JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

VOL. 29 JULY, 1937 No. 7

CONTENTS

Progress in Federal Conservation of Water Resources 1936–1937. By Abel Wolman 915

The Future of Water Allocation and Developments in Interstate Agreements. By Duane E. Minard 942

Discussion by Willard T. Chevalier 950

George S. Burgess 955

International and Interstate Pollution Problems. By J. K. Hoskins 960

Discussion by A. E. Berry 972

C. A. Holmquist 975

Samuel A. Greeley 976

Fluoride Content of Some Wisconsin Municipal Waters. By Donovan J. DeWitt and M. Starr Nichols 980

Fluorides in Illinois Water Supplies. By James G. Weart and C. W. Klassen 985

Discussion by L. E. Workman 996

J. A. Holmes 997

C. F. Deatherage 998

Tap Sterilizer for Water Sample Collection. By Carl Leipold 999

The Potassium Palmitate Test for Hardness. By Max Suter 1001

Discussion by L. A. Nalefski 1008

Experiences in Filtration. By John R. Baylis 1010

Public Safety as Related to Waterworks Operation. By T. W. Coleman 1049

Abstracts 1059

Coming Meetings v

Additions to Membership List vi

News of the Field 1

Discussion of all papers is invited

SECRETARY'S OFFICE, 29 WEST 39TH STREET, NEW YORK

All correspondence relating to the publication of papers should be addressed to Harry E. Jordan, Secretary, American Water Works Association, 29 West 39th Street, New York.

Because of the necessity for rigid economy, no reprints of articles will be furnished to contributors free of charge. Reprints may be purchased at the usual prices.

Subscription Price, $7.00 per annum

Single copies, to members—50 cents, to non-members—75 cents

REAL VALUE FOR YOUR CHLORINATION DOLLAR

CHLORINATION—
geared to your requirements

WHETHER your chlorine requirements call for fractions of an ounce per hour or thousands of pounds per day, there is a W&T Chlorinator designed to meet your specific need—built to give you dependable, accurate, low cost service today, tomorrow and for years to come.

Visible Vacuum Chlorinators, tried and proven in many thousand installations, are now available in all capacities from .03 pounds to 6000 pounds of chlorine per day. Does your job call for semi-automatic or full automatic control? A standard W&T equipment will meet your specifications, whether the use be for water works, sewage treatment, swimming pool or industrial chlorination.

You profit by choosing a W&T Chlorinator. Back of every equipment is a quarter century's experience in the design and manufacture of chlorine control equipment—an experience built upon well planned design, high calibre manufacturing and painstaking selection of the best materials. Now, more than ever, W&T are privileged to say "Whatever your requirements, we have a Chlorinator to meet them."

Ask for Technical Publications describing W&T Chlorinators

WALLACE & TIERNAN CO. INC.

Manufacturers of Chlorine and Ammonia Control Apparatus

NEWARK, N. J. Branches in Principal Cities

"The Only Safe Water is a Sterilized Water"

CHLORINATORS FOR WATER WORKS • SEWAGE PLANTS
SWIMMING POOLS • INDUSTRIAL PLANTS

SA-74

JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION
COPYRIGHT, 1937, BY THE AMERICAN WATER WORKS ASSOCIATION

Reproduction of the contents, either as a whole or in part, is forbidden, unless specific permission has been obtained from the Editor of this JOURNAL. The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings.
Vol. 29 JULY, 1937 No. 7

PROGRESS IN FEDERAL CONSERVATION OF WATER RESOURCES 1936–1937*

BY ABEL WOLMAN
(Chairman, Water Resources Committee)
(National Resources Committee, Washington, D. C.)

OUTLINE

BASIC HYDROLOGIC DATA AND RESEARCH
TOWARD A NATIONAL WATER POLICY
- Elements of a Sound Policy
- Pollution Control
- Irrigation
- Flood Control
- Hydroelectric Power
- Beach Erosion Control
- Regional Authorities

TOWARD COÖRDINATED WATER PLANNING
- Federal
- Interstate
- State

CONSTRUCTION
SUMMARY

During the last four years floods, drought, pollution and power have held the stage of dramatic interest of the people of the United States. Problems of too much water, too little water and too bad

* Presented at the Buffalo Convention, June 1937.

water are likely to continue to hold the stage for many decades in the future. The sacred oath of absolution before Osiris thousands of years ago will assume its importance one more: "I have not sullied the water of the Nile, I have not stopped its flow in good time, I have dammed up no canal."

Federal, regional, and state sub-divisions are becoming increasingly concerned with these problems. During the past twelve months all of these issues have received more emphasis than at any previous time in our history. Unprecedented floods, continued droughts, changes in water pollution situations and important decisions on power policy have forced national and local thinking into increasingly widened channels of water consciousness.

It is the purpose of this paper to set forth briefly what has occurred during the past twelve months, primarily in Federal operations and secondarily in other levels of government, in the use and control of water resources. What are the outstanding accomplishments in the fields of basic hydrologic data and research, in the evolution of a national water policy, in the development of coordinated and integrated Federal and state planning, and in the resultant construction enterprises of major character?

Water resources activities comprise (a) ordinary bookkeeping, or the uninterrupted observation and recording of nature's water transactions, at enough key locations to form a solid basis for the application of reasonable intelligence to the water-resources business; (b) scientific analysis of detailed and continuous water resources data; (c) appraisal of all pertinent facts so as to provide authoritative, accurate and comprehensive proposals for the actual construction and administration of water-resources undertakings, and (d) formulation of national water policy.

In each of these classes of activity much progress may be reported for the year. Progress has been uneven and much remains to be done to improve and strengthen the ground work upon which a comprehensive and integrated program of water conservation may be carried out during the next decades by Federal and local agencies.

BASIC HYDROLOGIC DATA AND RESEARCH

In September 1936, the National Resources Committee published a review of "Deficiencies in Basic Hydrologic Data." This was an effort to make clear the costs of ignorance of fundamental data. One newspaper correspondent facetiously, but accurately, described the document as a series of "H_2 Omissions."

Strong recommendations for improving the whole system of water resources bookkeeping for precipitation, snow surveys, stream flow, ground water levels, evaporation and water quality were set forth. In this work, for the first time, an effort was made to evaluate the data-collecting activities of Federal and state agencies as a whole, and to develop a means for improving them.

Increased budgetary allotments to the Federal and state agencies principally responsible for a systematic extension of the observations proposed are needed, but have not been made.

The collection of basic data, however, has been extended in connection with special area studies by Federal agencies. Notable among these are the experimental projects of the Soil Conservation Service for studies of erosion control practices, where observations of precipitation, run-off, silt content and ground water storage are generally made and related; and the experimental projects of the Forest Service for studies of relationship of vegetal cover to run-off, based upon observations of precipitation, run-off and ground water.

A sub-committee of the Water Resources Committee has completed a preliminary index of unpublished records of hydrologic data.

The publication of ground water well records on a national scale for the first time and the recent modification in form of publication of stream flow records by the U. S. Geological Survey according to recommendations of the Advisory Committee on Hydrologic Data, have been notable contributions to basic hydrologic knowledge.

The Water Resources Committee, through its Advisory Committee on Standards and Specifications for Hydrologic Data, is preparing a report on Deficiencies in Hydrologic Research, based on a review of current research, comparable with that on which the report on Deficiencies in Hydrologic Data was based. Among the current research projects are flood studies by the Geological Survey; studies of rainfall-run-off relationships by the Geological Survey, Weather Bureau, Soil Conservation, and Forest Service; studies by the Weather Bureau and the Geological Survey for improved flood forecasting; ground water research by the Geological Survey, Bureau of Agricultural Engineering, and Soil Conservation Service; suspended load investigations by the U. S. Waterways Experiment Station and by Soil Conservation Service; and plans for extension of studies of water pollution by the Public Health Service.

Special mention should be made of the important steps forward in flood forecasting accomplished by the cooperative efforts of the Weather Bureau, the Geological Survey and States in the Ohio River

basin, notably Pennsylvania. Chiefly as a result of financial contributions by Pennsylvania, a comprehensive flood forecasting system is being organized in that state. The expanded network of recording rain gages and the selection of "key" watersheds has already indicated a fruitful line of study which should be initiated in other sections of the United States.

During the year the U. S. Geological Survey also undertook a series of studies of floods in the major areas of flood damage, thus continuing scientific analyses of flood phenomena which analyses were begun in 1903 but discontinued a few years thereafter. Two of the Soil Conservation Service intensive watershed experiments were placed in operation during the year, but like most of the research initiated by that new bureau have not reached a stage at which conclusions may be drawn.

One of the many objectives guiding the work of the Soil Conservation Service has to do with the extent to which improved land-use and erosion-control practices are effective in the control and reduction of floods and in sustaining or augmenting dry weather flow in streams. Naturally, a number of related phenomena are being investigated concurrently, such as rainfall patterns, surface detention, infiltration, ground water studies, interception, evaporation, run-off assembly and routing, regulating effects of storage reservoirs, channel and valley storage, and flood wave propagation.

Sub-committees of the Water Resources Committee are also engaged at the moment upon the preparation of a summary of existing information regarding the effect of vegetal cover and land use practices on flood water run-off. This report should be available during the summer of 1937. A manual dealing with the design and construction elements involved in the development of small dams in various water conservation undertakings is also in preparation by a sub-committee of the Water Resources Committee and should be available in the summer of 1937.

TOWARD A NATIONAL WATER POLICY

Elements of a sound policy. The report of the National Resources Committee on "Drainage Basin Problems and Programs" was released under date of December 1936. In that document the Water Resources Committee emphasized the desirability and necessity of evolving a national water policy which would emphasize the interlocking relationship of various types of water problems and of water

and land uses. It pointed out, furthermore, the importance of evolving ultimately a coordinated policy of water use and control to supersede unrelated and uncoordinated special policies applicable to individual and isolated water problems.

The characteristics of a sound water policy were outlined as follows:

1. It will be concerned, in the final analysis, not with water per se, but with the promotion of public safety, public health, public convenience and comfort, the economic welfare of the public and the establishment or maintenance of a high standard of living.

2. It will seek to promote the maximum integrated use and control of water, within the shifting limits imposed by considerations of technical feasibility and of economic and social justification.

3. It normally will treat drainage areas as units with respect to their waters.

4. It will nevertheless scrupulously observe the rights of the several states both in intrastate and interstate streams.

5. It will recognize and abide by the axioms that facts are indispensable prerequisites to sound action, and that conclusions and commitments not based on predetermined facts almost certainly prove indefensible. In keeping with this recognition, it will promote by all feasible means the continuous assembly of the basic data essential for an evolving, unending water plan.

6. It will assign the cost of constructing and operating projects undertaken from time to time as suitable elements in an evolving water plan among the public and private agencies concerned in as close accordance as possible with the distribution of benefits.

7. In determining whether or not water projects are justifiable, and in distributing the cost of meritorious projects among the beneficiaries, it will take properly into account social benefits as well as economic benefits, general benefits as well as special benefits, potential benefits as well as existing benefits, wherever they are involved. Some of these benefits are not capable of exact measurement, but they are subject to reasonable appraisal, and their intangible nature will not justify their neglect in the future.

The importance of the drainage basin study lies primarily in focusing attention on water problems from regional and national standpoints. Its primary purpose of extending the vision of lay and professional people beyond the scope of local problems is already well attested by legislative efforts, by technical discussion and by the development of comprehensive programs in various parts of the country.

Pollution control. Although no actual progress in legislation has occurred in the pollution control field, the Water Resources Committee has issued a second report by a special Advisory Committee on Water Pollution. That Committee in its report dated February 23, 1937 concluded that, while it would be unwise for the Federal Government to assume entire responsibility for reduction of water pollution, progress would depend on Federal stimulation and aid, and coordination of the efforts of State and local governments. It submitted its opinion that a Federal statute with the following provisions would be constitutional and would provide the desirable kind of Federal stimulation and participation.

1. Designate an appropriate Federal division with authority: to make studies of water pollution and its control and to cooperate with State officials and other research agencies in such studies; to assist State officials in forming and administering interstate compacts for pollution abatement and to represent the Federal interest in such connection; and to review and report on the economic and technical feasibility of projects for pollution abatement for which Federal financial aid is requested.

2. Provide for Federal financial assistance for pollution abatement in the form of grants or loans or both for construction of necessary waste treatment works to State and subsidiary public agencies and in the form of loans for construction of necessary waste-treatment works to industrial or non-public agencies; such financial aid to be contingent upon approval by appropriate State and local and designated Federal agencies, and upon general policies established by Congress.

3. Provide rigidly that Federal grants-in-aid and loans be recommended by the Federal agency designated under (1) above, and be approved by an overlying public works agency.

4. Provide that all Federally financed water pollution investigations and abatement works initiated under the Act be cleared (for reconciliation of interests of other Federal, State or local agencies in pollution abatement or other affected water uses) through an appropriate coordinating agency, such as the Water Resources Committee, of the National Resources Committee.

5. Give Congressional consent to the negotiation of interstate compacts for the abatement of water pollution.

One act passed prior to 1937 has considerable influence in the general field of water pollution control. The Social Security Act, approved August 14, 1935, known as Public Law No. 271, 74th Con-

gress, in Title 6, "Public Health Work," authorizes (a) annual appropriation of $8,000,000 to be allotted by the Surgeon General with approval of the Secretary of the Treasury to the States, determined on the basis of their population, special health problems and financial needs, to assist them and their political subdivisions to maintain adequate public health services; and (b) annual appropriation of $2,000,000 to the Public Health Service for investigation of disease and problems of sanitation, including cooperation with the health authorities of any State upon request of the proper State authorities.

Legislation proposed in the 1937 Session has not passed both Houses. Senator Lonergan, in Senate Bill 13, has reintroduced an act comparable in essentials with Senate Bill 3958, introduced by him in the 1936 session. It has not yet been acted upon by either House.

The Barkley-Vinson Act introduced in January 1937, is still awaiting consideration by the Senate, having already been approved in the House.

Irrigation. No direct changes in national irrigation policy have been made. The machinery has been set in motion, however, for a reappraisal of the charges for water on Federal projects, and a precedent has been established for 100 per cent Federal contribution to multiple purpose water storage projects.

Public Law 742, 74th Congress, approved June 22, 1936, authorizes the Secretary of the Interior to investigate irrigation charges against owners of non-Indian lands under Indian irrigation projects and to adjust, defer, or cancel such charges if he finds land-owners unable to make payment on account of lack of soil fertility or of water supply, or of defects of irrigation works or for any other causes.

Public Law 519, 74th Congress, approved April 14, 1936, creates a Commission (two from Interior Department and one land-owner and water user on a United States Project) to investigate the financial and economic conditions on United States reclamation projects with reference to ability to pay water rights charges without undue burden, and to report and recommend to Congress on the best feasible comprehensive, economic plan for such water right payments; and extend for one year the moratorium on construction repayments provided in the Act of June 13, 1935, but reduced the moratorium to 50 percent of the repayments due. Owing to lack of funds, this Committee has never been appointed.

Public Law 738, 74th Congress, approved June 22, 1936 (the Flood

Control Act) includes authorization of construction at Federal cost of reservoirs providing storage for irrigation, without requiring water users to repay the construction cost of such storage (e.g. Caddoa Reservoir, Colorado, and Conchas Reservoir, New Mexico).

Flood control. The year 1936 marks an important milestone in flood control annals. The flood control program for the Lower Mississippi River was amended, and a national flood control policy was established.

Public Law 678, 74th Congress, approved June 15, 1936 (the Overton Act) amending the Flood Control Act of 1928, authorizes reservoirs for the first time as an element of the flood control plan for the lower Mississippi. It requires States or other qualified agencies to provide all necessary lands, easements and rights-of-way without cost to the United States; to hold and save the United States free from damages due to construction; to maintain and operate the completed works according to regulations prescribed by the Secretary of War; and to make the necessary alterations of highways and assume all damages due to such alterations. It provides for purchase by the United States of flowage rights in the Eudora, Morganza and West Atchafalaya floodways; provides for Federal construction of a limited number of railway and highway crossings over those floodways, and for Federal responsibility for drainage necessitated by floodway levees.

Public Law 738, 74th Congress, approved June 22, 1936, Flood Control Act, has special national significance in that it:

(i) Declares flood control on navigable waters or their tributaries a proper activity of the Federal Government in cooperation with States, their political subdivisions and localities thereof if the benefits to whomsoever they accrue are in excess of the estimated costs and if the lives and social security of people are otherwise adversely affected.

(ii) Places Federal investigation and improvement of rivers and other waterways for flood control and allied purposes under the jurisdiction of the War Department and Federal investigations of watersheds and measures for run-off and waterflow retardation and soil erosion prevention under the jurisdiction of the Department of Agriculture, except that these grants of authority shall not interfere with investigations and river improvements incident to reclamation projects undertaken by the Bureau of Reclamation pursuant to any general or specific authorization by law.

(iii) Requires States or subdivisions to assure provision without cost to the United States of necessary land easements and rights-of-way, to hold and save the United States free from damages due to the construction works, and to maintain and operate the completed works according to regulations prescribed by the Secretary of War.

(iv) Authorizes any two or more states to enter into compacts or agreements for the purpose of carrying out provisions of the Act.

(v) Authorizes construction of specific flood control projects (including reservoirs), and investigations of other specified projects; authorizes penstocks for future use in developing electric power to be installed in any dam authorized by the Act, when approved by the Secretary of War.

Allied purposes additional to flood control are specified in the Act in connection with the following authorized projects.

Water Conservation, Caddoa, Colorado

Irrigation and Water supply benefits, Conchas, New Mexico

Water supply, Hulah, Oklahoma

Water conservation and other incidental benefits, Lake Traverse, South Dakota.

Hydroelectric power. On January 18, 1937, the President appointed a Committee on National Power Policy, with the request that as its first assignment it make suggestions for the administration of the Bonneville project. He transmitted this Committee's recommendations on Bonneville to Congress, with his approval February 24, 1937, providing for a special provisional form of administration for the Bonneville project pending the establishment of a permanent administration for Bonneville, Grand Coulee, and other projects in the Columbia River Basin. At this writing, no legislation on the subject has been passed.

The Committee on National Power Policy, however made the following proposals:

1. That an Administrator be appointed by the Secretary of the Interior to maintain and operate the completed project, except the locks to be operated by the Secretary of War; the Administrator to act in consultation with an advisory board of three members appointed by the Secretaries of the Interior, War, and by the Federal Power Commission respectively.

2. That electric energy additional to that needed in operating the dam and its navigational facilities be generated and sold as rapidly

as markets can be found for it; the Administrator being authorized to provide transmission lines to existing and potential markets and for inter-connection with other Federal projects for power interchange.

3. That preference and priority in power sales be given to public and cooperative non-profit agencies, particularly for domestic and rural consumers, with 50 percent of firm power capacity reserved for such sale until January 1, 1939; with liberal policy in allowing time for such agencies to arrange for such purchases.

4. That authority be given to the Administrator to contract for sale of power at wholesale to public and cooperative agencies and to private agencies and persons in conformity with rate schedules approved by the Federal Power Commission; such contracts with their renewals and extensions to be effective for not over 20 years, and to contain provisions for periodical equitable adjustments of rates; and contracts with private agencies or persons to permit cancellation on 5 years notice if the power is needed for sale to public or cooperative agencies.

5. That rate schedules, prepared by the Administrator for approval by Federal Power Commission, be fixed with a view to encouraging widest possible use of electricity while recovering the cost of production and transmission and amortization of construction over a reasonable period of years; computed cost may include a fair allocation of part of the cost of features of the Bonneville project which have joint value for electric power production together with other purposes; and rates may be made uniform throughout prescribed transmission areas.

6. That general Administrative provisions are that Civil Service laws apply to all except experts in the professional or technical fields, and that accounting follow methods as prescribed by the Federal Power Commission.

7. That the project should become self-supporting, but in the meantime funds will be needed for initial construction of transmission lines, operation and administration. All receipts should be covered into the general treasury.

The Committee on National Power Policy consisted of the following members:

Harold L. Ickes, Secretary of the Interior, Chairman
Frank R. McNinch, Federal Power Commission
Frederic A. Delano, National Resources Committee
James M. Landis, Securities and Exchange Commission
John M. Carmody, Rural Electrification Administration

Beach erosion control. During the past year the Federal Government assumed, for the first time, partial responsibility for the control of beach erosion.

Public Law 834, 74th Congress, approved June 26, 1936, regarding Beach Erosion, declares the policy of the United States to assist in the construction where Federal interests are involved (but not maintenance) of works for improvement and protection of beaches along the shores of the United States; authorizes the Beach Erosion Board to investigate suitable methods of beach protection, to advise States or subdivisions or individuals on appropriate locations for recreational facilities and to publish data concerning beach protection, the United States not to bear over 75 percent of the cost of any specific investigation; and authorizes the Board to report on the advisability of adopting projects, on the extent of Federal interest involved and on the extent of expense which should be borne by the United States.

Regional authorities. The increasing tendency of public thinking toward broader geographical bases of water use and control is indicated by the variety of regional authoritie proposed in Congress to provide for the coordinated use and control of water.

In the course of time it is probable that a regional plan of approach to water problems will be crystallized from the many proposals now in Congress. What form these will take it is too early to predict, but it may be again emphasized that extension of viewpoint, both geographic and technical, is occurring. Its validities and controls are important subjects for lay and professional discussion during the next few years.

TOWARD COORDINATED WATER PLANNING

Federal. On the Federal level of coordination and integration of water use and control a number of important phases of progress may be noted. It is impossible to elaborate all of these in the detail which they deserve. Space requirements limit the discussions to a brief enumeration of the outstanding contributions in this respect during the year.

1. Report of the National Resources Committee to the President, December 1936, presenting the Water Resources Committee's report on Drainage Basin Problems and Programs, is probably the major contribution of the past year toward coordinated thinking in the water field. It undertakes to determine the principal water problems in the Country's various drainage areas, to outline an integrated

pattern of water development and control designed to solve those problems, and to present specific projects of construction and investigation as elements of the integrated pattern or plan, with priorities of importance and time. It represents the first attempt to formulate a nation-wide water plan and program through the joint efforts of Federal, State and local agencies, official and non-official, and to give joint consideration to the inherent relationships between land and water problems and between various types of water problems, the needs of the various localities in the drainage basin, and the possibilities of multiple-purpose developments. The programs and projects are presented without specific assumptions as to how any program or any individual project should be financed or administered, or as to the extent of Federal responsibility for initiation and financial support. This document is of basic value to all Federal agencies concerned in water planning, in that it builds a frame work of reference to interrelated water needs in each drainage region, to which their specific projects may and should be harmoniously related.

The study, of course, was in its nature preliminary. It should undoubtedly stimulate thinking in terms of entire basins. The serious limitations in fact and in perspective are correctable as future water requirements are more accurately estimated and as changes in density of population, in land use, in industry and in social conditions are evaluated, currently adjusted and as new policies and programs evolve.

A framework of a national water plan has been proposed that will not only permit but should stimulate constructive action on sound lines along a broad front. As a moving plan it is to be adjusted, filled in and extended to meet changing conditions. To this task of adjustment, on the basis of further local and central investigation, the activities of the Water Resources Committee must be directed for some time to come.

2. By the request of the President on July 14, 1936, the Water Resources Committee served as a clearing agency for emergency flood control projects in the emergency program presented in August 1936.

3. The service of inter-bureau information on proposed land drainage and water storage projects, established by Executive memorandum February 1, 1936, in which all Federal agencies report such proposals to the Water Resources Committee, has been extended to include projects of the Federal Emergency Administration of Public Works by PWA Administrative Order No. 174, October 1, 1936. The Committee in turn disseminates the information in form for ready

reference by monthly bulletins to all Federal agencies concerned in water development.

4. The Acting Director of the Bureau of the Budget, by direction of the President, in Circular No. 338, May 14, 1936, called upon all Federal agencies proposing to make any investigation concerning floods or flood control to transmit to the National Resources Committee information on the character, purpose, scope and probable duration of the proposed activity; its legal authorization; the probable number of persons to be employed, their salaries, and the estimated cost for the current fiscal year and the total cost; and designation of the appropriation from which the expenditures are proposed to be made. It directed the National Resources Committee to advise the head of the reporting agency as to what similar work has been or is being done by any other agency; and to furnish to the Bureau of the Budget a copy of its report together with a copy of the information received from the reporting agency.

5. Notable coordination of their respective programs of investigation and planning has been achieved by the voluntary action of the Corps of Engineers and the Bureau of Reclamation, the major Federal agencies constructing water developments, in a number of areas where irrigation is involved.

6. Similar coordination has been achieved by the Corps of Engineers and the Federal Power Commission with respect to investigations and conclusions on several major projects authorized by the 1936 Flood Control Act which involve potential hydroelectric power development.

7. Pursuant to the provisions of the 1936 Flood Control Act, plans are being made for joint investigations by the Department of Agriculture on drainage areas for which flood control plans are undertaken by the Corps of Engineers.

8. The year has been marked also by an increased realization of the part which wildlife conservation should have in programs for water use and control. This has been reflected in the Drainage Basin Program and in the preparation of comprehensive flood-control plans.

Interstate. In the intermediate level of Government between the central and the State agencies, a territory in which in the past progress has been made difficult by the non-existence of constituted authority, real progress has been made both by voluntary and legislative interstate action. Tangible results of the efforts of both Federal and

State groups toward establishing interstate policies and machinery will appear from the very brief summary presented below. As pointed out in the report of the Water Resources Committee in 1936, these effects are not all in a single direction or upon a standardized basis. They should continue to be of varied character and to use techniques of different approach. The activities listed will no doubt result in the development of a variety of formulae which may be applicable in the difficult territory of interstate action. Some of the outstanding contributions towards interstate thinking are herewith presented.

1. The joint investigations made with cooperation from the Water Resources Committee and the program adopted in the basin of the Red River of the North by the States of Minnesota, North Dakota and South Dakota have resulted in interstate compacts. A bill (Senate No. 1570) to permit such compacts, passed the Senate March 19, 1937.

2. The joint investigation organized in the Upper Rio Grande Basin by the Water Resources Committee in cooperation with the Rio Grande Compact Commission and with coordinated cooperation of a number of Federal agencies, will be completed during June 1937. It gives substantial promise of becoming the means of harmonizing critical conflicts in that region.

3. The water storage to be provided by the Caddoa Reservoir, authorized by the 1936 Flood Control Act, forms the basis of agreement between the States of Colorado and Kansas, composing an old conflict over water rights in the Upper Arkansas River Basin.

4. The Council of State Governments has sponsored and organized an Interstate Conference on the Delaware River composed of official representatives of the States of New York, New Jersey and Pennsylvania, for the purpose of aiding in the formulation of an acceptable interstate plan for solution of the more pressing water problems. The National Resources Committee is cooperating in furnishing a staff technician. An interstate compact on water pollution has been drafted by the Engineering Committee of the Conference.

5. The Council of State Governments has organized an Interstate Conference on the Ohio River, composed of official representatives, of the States of New York, Pennsylvania, West Virginia, Virginia, Kentucky, Ohio, Indiana, and Illinois. The Conference will concern itself with the development of a program of water use and con-

trol embodying the pressing problems of floods, pollution, navigation and power.

6. Public Resolution 104, 74th Congress, approved June 8, 1936, grants consent of Congress for any two or more of the following States to negotiate and enter into agreements or compacts for conserving and regulating the flow, lessening flood damage, removing sources of pollution of their waters, or making other public improvements on any rivers or streams whose drainage basins lie within any two or more of these States: Maine, New York, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, Pennsylvania, West Virginia, Kentucky, Indiana, Illinois, Iowa and Ohio.

The Resolution covers North Atlantic Drainages down to the Susquehanna (excepting Maryland); Lake Erie, Lake Ontario, and St. Lawrence drainages, and Ohio River Drainage (except Virginia and North Carolina).

7. Interstate compacts have been drawn, relative to flood control in the basins of the Connecticut and Merrimack Rivers, and have been ratified by the Legislatures of Vermont and Massachusetts.

8. A number of proposals for interstate agreements are now in Congress waiting for consideration. Some of the more important of these are:

(a) Idaho and Wyoming, respecting the disposition and apportionment of the waters of the Snake River and its tributaries.

(b) Montana, North Dakota, South Dakota, and Wyoming, for division of the waters of the Little Missouri River.

(c) Montana and Wyoming, for division of the waters of the Yellowstone River.

(d) Maryland, Virginia, West Virginia, Pennsylvania, and the District of Columbia, respecting the creation of a Potomac Valley Conservancy district for the prevention or abatement of harmful pollution of the waters thereof.

9. The Pacific Northwest Regional Planning Commission made a report on Water Resources and their Future Development, October 10, 1936, asking for consideration and further development of certain fundamental principles, for continuation of planning on a drainage basin basis.

10. The New England Regional Planning Commission is currently preparing a report on the planned development of the water resources of New England.

11. Under allotments made prior to the current fiscal year, studies by the Bureau of Reclamation in the Colorado River basin have been in active progress during the year to determine the irrigable lands within the basin, and the water supplies available for them; thus determining how much water may be beneficially used within the basin, and what surpluses appear available for exportation outside of the basin.

Intra-state. Within the States truly remarkable activity in water resources study marks the last year. One may only view with gratification the display of interest in the general water problem and in its local details. State after state is approaching the pressing issues of water use with new vigor and with continually expanding perspective. A simple record of these efforts is impressive. As these activities continue, a detailed analysis of their trend, their significance and their hopes for the future should bring forth fruitful results. It is perhaps too early to attempt such an analysis at this date, since so many of the activities of the individual states are in a formative period. The stimulation afforded by the Federal Government through the National Resources Committee has done much to carry forward the cooperative studies and reports started in 1936 in connection with the Water Resources Committee's drainage basin study.

For the purpose of stimulating and assisting in water planning, the National Resources Committee is providing part-time consulting services of the following Water Consultants who assisted in the former drainage basin studies in the areas to which they are assigned:

Mr. J. C. Stevens, to the Colorado Basin areas in Arizona, California, Nevada, Utah, Wyoming, Colorado and New Mexico.

Mr. W. L. Huber, to California and Nevada, exclusive of the Colorado Basin.

Mr. S. B. Morris, to Washington, Oregon and Idaho.

Mr. S. T. Harding, to Montana, and Wyoming, exclusive of the Colorado Basin.

Mr. W. W. Horner, to Iowa, Missouri, Arkansas, Oklahoma and Texas.

Mr. N. B. Jacobs, to the Delaware Basin areas in New York, Pennsylvania, and New Jersey.

Mr. E. S. Cullings, to New York.

Mr. H. T. Critchlow, to the New England States.

CONSTRUCTION

The significance of previous expositions in this report may be demonstrated, in one direction at least, by the actual construction expenditures during the past year. A great many enterprises were started several years ago, but appropriations and allotments from July 1, 1936 to May 15, 1937, are important in illustrating the extent to which the Federal government is committing itself to large operations in the water resources field.

In the Report of the Water Resources Committee for the 12 month period ending June 30, 1936, it was pointed out that expenditures for water resources purposes had reached a figure of $376,000,000 in 1935.

TABLE 1

Summary of Federal Appropriations and Allotments to Projects for Water Use or Control, July 1, 1936–May 15, 1937*

Navigation	$128,312,000
Flood Control	33,662,000
Hydro-Electric Power	8,434,000
Water Supply	81,376,000
Sewerage, and Stream-pollution Control	132,620,000
Recreation and Wild Life Conservation	380,000
Stock-water Development (Springs and Reservoirs)	3,001,000
Drainage	15,950,000
Irrigation	17,235,000
Multiple Purpose	208,332,000
Total	$629,302,000

* Amounts are approximate only, and subject to revision. Allotments not classifiable by type are included under "Multiple Purpose."

In table 1 a summary of the appropriations and allotments for the period of July 1, 1936 to May 15, 1937, is presented. This summary covers Federal expenditures only and gives a reasonably accurate picture of the distribution of construction costs for various functions. The total appropriations and allotments for this period for Federal purposes, of $629,000,000 exceed the amount for 1935, which was the highest expenditure for Federal construction for water use and control in the history of the United States.

For purposes of record, the construction activities in the various subdivisions of water resources are listed in tables 2, (navigation), 3 (flood control), 4 (power development), 5 (irrigation), 6 (water supply) and 7 (pollution).

TABLE 2

Major Federal Navigation Projects Under Construction During Year Ending June 30, 1937

PROJECT, NAME AND LOCATION	DESCRIPTION—PROJECT DEPTH	STATUS (MAY 15, 1937)
	feet	
Enlargement and Deepening of Harbor Channels		
Boston, Mass.	40	In progress
New York, N. Y.	40	In progress
San Diego, Cal.	35	In progress
Galveston, Texas City, and Houston, Tex.	34	In progress
Port Arthur and Beaumont, Tex.	32	In progress
Freeport, Tex.	32	In progress
Miami, Fla.	30	In progress
Tampa, Fla.	30	In progress
Stockton, Cal.	30	In progress
Trenton, N. J.	25	In progress
Great Lakes Harbors (many separate projects)	21	In progress
Canal Deepening and Enlargement		
Cape Cod Canal, Mass.	32	40% complete
Chesapeake & Delaware Canal, Md. and Del.	27	30% complete
New York Barge Canal	14	In progress
New Seaports		
Morehead City, N. C.	30	Completed during year
Brownsville, Tex.	25	Completed during year
Columbia River above Bonneville, Wash. and Ore.	26	Locks and dam 80% complete

Note: All of the above projects, under the Corps of Engineers, were begun before July 1, 1936. No new projects of major importance, in these classifications, were begun during this fiscal year.

River Canalization, Locks, and Regulating Dams		
Mississippi River above St. Louis, Mo.	9-ft. navigation, 693 miles to Minneapolis, 26 locks and dams	Most of locks and dams completed; 3 completed in 1936; 7 scheduled for completion in 1937 and 4 in 1938

TABLE 2—*Concluded*

PROJECT, NAME AND LOCATION	DESCRIPTION—PROJECT DEPTH	STATUS (MAY 15, 1937)
	feet	
Illinois Waterway, Ill.	9-ft. navigation between Lake Michigan and Mississippi R., through canalization of Illinois River	Three passing locks in Calumet Sag completed; modern locks and dams at La Grange and Peoria in progress
Ohio River System	Improvement of present 9-ft. navigation (extending 128 miles up the Monongahela, 61 miles up the Allegheny, and 90 miles up the Kanawha) by modern locks and dams, and by dredging for 500 foot channel width in Ohio R.	Work in progress on last cofferdam of Gallipolis Dam, Ohio R. Tygart Dam, for regulation of Monongahela R., 86% completed. Winfield Dam, on Kanawha R. at head of Gallipolis pool, over 50% completed; this will complete the 9-ft. Kanawha project
Tennessee River System	9-ft. navigation, 650 miles between Knoxville and the Ohio R., by 9 locks and dams on main stream (of which 2 were built before TVA), with regulation from 3 dams on tributaries (Norris, Hiwassee, and Fontana)	TVA Dams: main stream: Wheeler Dam completed; Pickwick Dam (3rd yr.) 75% complete; Guntersville Dam, 30% complete Chickamauga Dam, 25% complete. Tributary Dams: Norris Dam complete; Hiwassee Dam well under way
Missouri River	6-ft. navigation from mouth to Sioux City, Iowa; by dredged channel with necessary supplementary dry-season flow provided by Fort Peck Reservoir	Dredging in progress below Omaha; Fort Peck Dam 60% complete

TABLE 3

Major Federal Flood Control Projects Under Construction During Year Ending June 30, 1937

PROJECT, NAME AND LOCATION	DESCRIPTION	STATUS (MAY 15, 1937)
Begun before July 1, 1936:		
Winooski River, Vt.	Two flood detention reservoirs	Completed
*Tygart River, Tygart Dam, W. Va.	Navigation & flood control	86% complete
Muskingum Valley, Ohio	System of 14 flood control reservoirs	81% complete
Lower Mississippi Valley	Levees, 1928 standard grade and section	Practically completed
*Missouri River, Fort Peck Dam, Mont.	Navigation regulation and flood control	60% complete
Los Angeles County, Cal., Flood Control	Channels, bank protection, debris basins, and storage reservoirs	About 25% complete San Gabriel Dam No. 1 over 50% complete
Rio Grande, Caballo Dam, N. M.	Flood storage & irrigation	About 25% complete
Rio Grande; El Paso-Juarez Valley, Tex.	Levees & channel work	70% completed
Rio Grande; Lower Valley	Levees and floodways	In progress
Colorado River, Tex. Buchanan (Hamilton) Dam	Flood control and power	75% complete
Begun since July 1, 1936:		
Winooski (Little) River, Vt., Waterbury Dam	Flood control and power	About 70% complete
Yazoo Basin, Miss., Sardis Dam	Flood control reservoir	Begun in 1936
Canadian River, N. M., Conchas Dam	Flood control, irrigation, and power	Contract let, Sept. 1936
Colorado River, near Austin, Tex., Marshall Ford Dam	Flood control and power	Contract let, Dec. 1936
Colorado River, Tex., Roy B. Inks Dam	Flood control	Begun in summer of 1936, 65% complete

* Already noted under *Navigation*, Table 2.

TABLE 4

Major Federal Projects having Hydro-Electric Power Features Under Construction During Year Ending June 30, 1937

PROJECT, NAME AND LOCATION	DESCRIPTION	STATUS (MAY 15, 1937)
Boulder Dam, Colorado River, Ariz., Nev.	Flood control, power and irrigation	Power first delivered to Los Angeles Oct. 9, 1936; installation of additional power units in progress
*Bonneville Dam, Columbia River, Wash., Ore.	Navigation and power development	80% complete
Ruby Dam, Skagit River (for city of Seattle, Wash.)	Power development	Begun during fiscal year
Grand Coulee Dam, Columbia River, Wash.	Power and irrigation	25% complete
Sutherland Project, Platte River Public Power and Irrigation District, Neb.	Power and irrigation	99% complete
Columbus Project, Loup River Public Power District, Neb.	Power	71% complete
Tri-County Project, Central Nebraska Public Power and Irrigation District	Power and irrigation	7% complete
North Loup Public Power and Irrigation District (centered at Ord, Neb.)	Power and irrigation	Begun late in 1936
Middle Loup Power and Irrigation District, Neb.	Power and irrigation	Begun in Dec. 1936

(PWA allotments totalling $8,434,000 were made to 5 water power projects during the fiscal year.)

* Already noted under navigation, Table 2.

(See also Casper-Alcova project, Table 5.)

TABLE 5

Major Federal Irrigation Projects Under Construction During Year Ending June 30, 1937

PROJECT, NAME AND LOCATION	DESCRIPTION	STATUS (MAY 15, 1937)
Begun before July 1, 1936:		
Rye Patch Dam, Humboldt River, Nev.	Local irrigation project	Completed, 1936
Imperial Dam, Colorado River, Ariz., Calif.	Diversion for All-American and Gila Canals	50% complete
All-American Canal, from Colorado River, Calif.	For irrigation in Imperial and Coachella Valleys, Calif.	60% complete
Lower Gila Project, Ariz.	First unit, 150,000 acres; canal and pumping lifts from canal from Imperial Dam, Colorado River	15% complete
Taylor Park Dam, Uncompahgre Project, Colo.	Supplemental irrigation	60% complete
Boise-Payette Project, Idaho: Payette Division	Main canal from Black Canyon Dam, and pumping units; and additional storage near Banks, Idaho	10% complete
Moon Lake Project, Duchense River Basin, Utah	Supplemental irrigation, by supplemental storage and feeder canals:	
	Moon Lake Dam, Lake Fork	60% complete
	Midview Dam, Lake Fork	75% complete
	22-mile Duchesne Feeder Canal	Completed Oct. 1936
Ogden River Project, Utah	Supplemental water supply for City of Ogden and nearby irrigation:	
	Pineview Dam	95% complete
	11-mile Canal and Ogden River Siphon	Contract let, 1936
Yakima Project, Wash. Roza Division	110-mile main canal, power plant, pumping plants and laterals for 72,000 acres	6% complete

TABLE 5—*Continued*

PROJECT, NAME AND LOCATION	DESCRIPTION	STATUS (MAY 15, 1937)
Begun before July 1, 1936 —Continued:		
Owyhee Project, Oregon-Idaho (Snake River Basin) near Ontario, Oregon	Irrigation, 65,000 acres new land and supplemental on 45,000 acres previously irrigated	85% complete
Casper-Alcova Project, North Platte River, Wyo.	River regulation, power development, and irrigation:	
	Seminoe Storage & power dam	25% complete
	Alcova diversion dam	70% complete
	Distribution system	30% complete
Riverton Project, Wind River Basin, Wyo.	Continuation of construction to enable adequate settlement: comprises Bull Lake Storage Reservoir; main canals and laterals; power plant at existing Pilot Butte reservoir; and drainage:	
	Bull Lake Dam	50% complete
Shoshone Project, Wyo. Heart Mountain Division near Cody, Wyo.	Main canal, 28 miles from existing Shoshone Reservoir, and laterals and drainage for 41,000 acres	Tunnels 60% complete
Sun River Project, near Fairfield and Great Falls, Mont.	Remaining construction on $9,000,000 project consists of completion of canals and drains	90% complete
Alamogordo Dam, Pecos River, Carlsbad Project, New Mexico	Additional storage to replace old project storage lost by reservoir silting	Begun March 1936; 75% complete
Begun Since July 1, 1936:		
Salt River Project, near Phoenix, Ariz.	Supplemental storage, Bartlett Dam	12% complete
	Reconstruction of spillways of existing dams	In progress

TABLE 5—*Concluded*

PROJECT, NAME AND LOCATION	DESCRIPTION	STATUS (MAY 15, 1937)
Begun Since July 1, 1936 —Concluded:		
Central Valley Project, Calif.	A $170,000,000 comprehensive regional water conservation project, embracing seven major divisions. Of these:	
	Contra Costa Canal	Contract awarded 1937
	Friant Dam	Specifications ready
Provo River Project, Utah	Supplemental supply for irrigation; transmountain diversion from Duchesne River, with new storage and improved distribution system	Investigation of transmountain diversion completed; specifications being prepared
Pine River Project, near Ignacio, Colo.	Vallecito storage reservoir for supplemental irrigation	Contract awarded March 1937; construction begun

(See also Irrigation and Power Projects in Nebraska, listed in Table 4.)

TABLE 6

Major Federally-aided Water Supply Projects Under Construction During Year Ending June 30, 1937

PROJECT, NAME AND LOCATION	DESCRIPTION	STATUS (MAY 15, 1937)
Denver, Colo.	Supplemental supply from Colorado River headwaters by trans-mountain diversion through Moffat Tunnel; filtration plant; dam	Nearing completion
Colorado Springs, Colo.	Dams and pipe lines	Completed, 1937
Little Rock, Ark.	Dams and pipe lines	Nearing completion
Springfield, Ill.	Filter plant	Completed late in 1936
Cincinnati, Ohio	Filter plant	40% complete Dec. 31, 1936
Milwaukee, Wis.	Filter plant	80% complete Dec. 31, 1936
Baltimore, Md.	Water tunnel	Under construction
Los Angeles, Calif.	Metropolitan Water Supply System	
	Parker Dam, Colorado River	Construction in progress
	Colorado River Aqueduct	Construction in progress
	Cajalco Reservoir	Construction in progress
	Mono Craters Tunnel	Construction in progress

PWA during the year May 1, 1936–April 30, 1937 made allotments for water supply projects as follows:

Water mains	10
Filtration plants	7
Reservoirs	16
Complete Waterworks	168
Total	201

TABLE 7

Major Federally-aided Projects for Abatement of Stream Pollution, Under Construction During Year Ending June 30, 1937

PROJECT, NAME AND LOCATION	DESCRIPTION	STATUS (MAY 15, 1937)
Los Angeles County, Calif. Sanitation District: White Point Outfall Sewer	Main Outfall	In progress; inshore half was completed during 1936
Denver, Colo.	Sewage treatment plant	Under construction
Minneapolis-St. Paul, Minn.	Twin Cities Sewage Plant	Under construction
Chicago, Ill.	$58,630,000 sewage treatment program	Completion expected in 1938
Cleveland, Ohio	Sewage treatment plant	Will go into service 1937
Buffalo, N. Y.	Sewers and sewage treatment plant	Will go into service 1938
Niagara Falls, N. Y.	Sewage treatment plant	About 30% complete
New York City, N. Y.	Coney Island (Chemical) sewage treatment plant	Put in operation 1936
	Wards Island sewage treatment plant	To be completed late in 1937
	Tallmans Island sewage treatment plant	Construction begun, 1936
Washington, D. C.	Sewage treatment plant	Completed 1937
Atlanta, Ga.	Sewers and sewage treatment plant	Under construction
Acid mine drainage reduction: Pennsylvania, Maryland & West Virginia	Sealing abandoned workings	Substantial progress made

PWA during the year May 1, 1936–April 30, 1937, made allotments to the following numbers of projects:

Sewage disposal plants	81
Sanitary sewers	41
Storm sewers	7
Combined sewers	3
Combined sewer and water systems	13
Total	145

SUMMARY

From the material herein presented, certain generalizations may be warranted.

1. Real progress has been made in establishing those areas of basic hydrologic data and research in which important and costly deficiencies are operative. Quantitative evaluation of these costs of ignorance, resulting from the failure to accept the ordinary and simple precepts of bookkeeping are difficult to make. They do not lend themselves to dramatic presentation. They are at the foundation, however, of anything that may be done in the future for the adequate correction of any or all of the problems of water use and control.

2. A beginning has been made in the formulation of a national water policy, in which the area of thinking is being deliberately and consistently expanded beyond the limited local perspective. Evidences of widening horizon of conception and of an extension of functional relationships are accumulating daily.

3. Important steps forward in coordination and integration of planning for water resources development have occurred during the last few years, on the Federal as well as interstate, state and local levels of government with an increasing emphasis on multiple use, on integration, and on more comprehensive policy.

4. Construction on the part of the Federal Government and of State and local subdivisions thereof is progressing rapidly. With problems of flood, drought, pollution and power in the public mind it is probable that this emphasis on water resources construction will continue.

THE FUTURE OF WATER ALLOCATION AND DEVELOPMENTS IN INTERSTATE AGREEMENTS*

By Duane E. Minard

(Hobart, Minard & Cooper, Attorneys at Law, Newark, N. J.)

WATER RIGHTS

The doctrines of water rights which came into operation on the western hemisphere, particularly that part thereof which was settled by Europeans, came from two different and distinct medieval sources, the Civil Law of the Roman Empire and the Common Law of England.

Under the Civil Law navigable waters, fresh or tidal, belonged to no one, and hence were the common property of all.

The genus of the Common Law was different; it attributed to everthing some definite form of ownership. Tidal waters, to mean high water, including the great oceans, belonged to the King, and were therefore available for the use of all the King's subjects, subject to the right of access for owners of the ripa, or bank, above mean high water.

On fresh water streams, with which we are here concerned, the Common Law gave the riparian owners property and title to the bed of the stream to the thalweg, or middle of the main channel, and the right to the undiminished flow of the water, subject to the public easement of navigation, where navigation was feasible, and the right to use the water for any purpose pertaining to the occupancy or use of the ripa or adjacent upland. The riparian owner could *consume* as much water as his family and stock required, and he could *use* all the water required for power or irrigation, provided he returned such water to the stream within his property limits, unless other rights were acquired from the owners of adjacent property affected.

The Civil Law maintained the same rule on fresh water streams, navigable for any kind of craft, as on tidal waters, and on non-navigable streams it recognized the right of preemption of waters according to priority and necessity.

* Presented at the Buffalo Convention, June, 1937.

Generally speaking, the English Common Law rule was applied, and still applies, in the humid areas of the eastern part of the United States but in the arid regions of the west the Civil Law rule of preemption was originally adopted as a result of the necessities of the settlers, and still prevails, through recognition by, and protection of, the courts.

No attempt will be made to cite the numerous authorities of our courts and jurists on these two divergent rules. The latest general review that has been noticed is "Fifty Years of Water Law" (Samuel W. Wiel), published in *50 Howard Law Review 252*.

While this is a nation-wide organization dealing with such problems throughout the country, attention is here given to allocation and development in interstate agreements respecting waters, primarily to the territory in which the English Common Law rule has been followed.

PUBLIC AND PRIVATE RIGHTS

However secure the property rights of riparian owners in the bed and undiminished flow of the waters of fresh water streams may be under the laws of the states and decisions of the courts, they have always been subject to the police powers of the state, and could be taken, or diminished, for the benefit of the public upon payment of just compensation. Under the police power, or the power of eminent domain, municipalities, by legislative authority, have been able to secure water supplies from streams within a state.

INTERSTATE STREAMS

There are a number of important fresh water streams in the United States which flow through more than one state, or whose main channels form the boundary between states. The diversion of waters from such streams in one state for water supply purposes therein, particularly those involving a transfer of the waters out of that watershed, has caused a number of important litigations between states, or the municipal subdivisions of different states, and the rights of the different states in such cases have been defined by the Federal Supreme Court in the controversies between Connecticut and Massachusetts involving the diversion, into another watershed, of waters from tributares, in Massachusetts, of the Connecticut River, and between New Jersey and New York involving the diversion, into another watershed, of waters from tributaries, in New York, of the Delaware River.

In both of those cases the plantiff states invoked, *in parens patriae*, the English Common Law right to the undiminished natural flow of the streams, for the benefit of their respective riparian owners, as well as for other public, or quasi public, benefits.

SUPREME COURT DECISIONS

In the Great Lakes Diversion case several states, along the lakes east of Illinois, invoked the Common Law rule to restrain the diversion of water from Lake Michigan into the Mississippi River basin as a means of flushing the Chicago river, but while the complaining states were successful to a degree, that case was complicated by certain questions of Federal War Department jurisdiction and permits.

The Connecticut-Massachusetts and the New Jersey-New York cases were free from that complication and present clear-cut issues on the right of states to divert, from tributaries within their own territorial limits, water from rivers that flow through several states.

The question arises as to what extent, if any, modification of the Common Law rule was made by the court in its decisions in those cases.

The court has not attempted to reconcile the two divergent theories of Appropriation and the Common Law rule. What they did in the Connecticut and New Jersey cases was to reconcile the rights of interested states, in all of which the Common Law rule generally prevailed. The court refused to exert its extraordinary power to control the conduct of one state at the suit of another unless the threatened invasion of rights is of serious magnitude and established by clear and convincing evidence, and it held that the burden of proof in such a case is much greater than that generally required to be borne by one seeking an injunction in a suit between private parties.

With respect to Connecticut's insistence upon the enforcement of the strict Common Law rule, the court held that in suits between states, federal, state and international law is considered and applied as the exigencies of the particular case may require, and that the determination of rights of contending states in respect to the use of streams flowing through them does not depend upon the same considerations and is not governed by the same rules of law that are applied in such states for the solution of similar questions of private right. The court expressly refused to adopt the principle of an

equal division of the waters of an interstate stream among the states through which it flowed; it held that upon a consideration of the pertinent laws of the contending states and all other relevant facts, the court will determine what is an *equitable apportionment* of the use of such waters.

The Connecticut case was decided in favor of Massachusetts on the failure of the plaintiff to sustain its burden of proof, but without prejudice to its right to a suit against Massachusetts whenever it should appear that substantial interests of Connecticut are being injured through a material increase in the amount of water taken.

In the New Jersey case the same general principles were followed by the court. Mr. Justice Holmes, in delivering the opinion of the court, said:

> "A river is more than an amenity, it is a treasure. It offers the necessity of life and must be rationed among those who have power over it. New York has the physical power to cut off all the water within its jurisdiction, but clearly the exercise of such a power to the destruction of the interest of lower states could not be tolerated. On the other hand equally little could New Jersey be permitted to require New York to give up its power altogether in order that the river might come down to it undiminished. Both states have real and substantial interest in the river that must be reconciled, as best they may be. The different traditions and practices in different parts of the country may lead to varying results, but the effect always is to secure an equitable apportionment without quibbling over formulas."

The court found that New Jersey had sustained its burden of proof of substantial damages that would result from the diversion of quantities above a maximum amount which the court allowed, subject to certain conditions imposed upon New York respecting the treatment of sewage and the maintenance of a minimum flow during low-water periods by increasing the reservoirs for that purpose.

In both cases (Connecticut v. Massachusetts, and New Jersey v. New York) the court re-affirmed the Common Law right to undiminished flow as between private parties, but followed the doctrine of *equitable apportionment* of the waters of interstate streams as between the states through which the streams flowed. Both decisions declared the principle that the highest uses of water were for

drinking and other domestic purposes, but of course, that does not mean that those are the only purposes that should be considered in dealing with the development and conservation of the waters of such streams.

VOLUNTARY AGREEMENTS

There are no serious legal difficulties involved in agreements between states. A compact agreed to by representatives of different states must be ratified by the legislatures of the states involved, and approved by Congress, under the federal constitution. It then remains unchangeable except by mutual consent of the parties and the approval of Congress.

The real difficulties have, heretofore, been political, within the states involved. Each state may be represented in the negotiations by fair-minded, intelligent, competent and conscientious representatives, and their compact may be eminently fair and sound, but when it comes before the legislatures for ratification, its merits are often the least of the considerations which govern their action. Sectional prejudice, political expediency, and other irrelevant, often selfish, considerations which have no relation whatever to the merits of the proposition, are apt to be controlling, and the considerations which may influence the legislature of one state may be totally different from those which influence the legislature of another state.

While Congress may be relied upon to approve whatever the States ratify, this method of interstate agreement has many disadvantages. These difficulties are peculiar to the United States of America where the sovereignty of the several states is prescribed by the federal constitution and it is necessary to deal with the situation on that basis.

THE BROADER QUESTION

The real question that confronts us is broader than strict legal rights. A court is not the best place to decide questions of policy, or the allocation or distribution of interstate waters. Litigation may, or may not, stop a given project, but cannot fully solve such problems.

However, with the doctrine of "Equitable Apportionment" of the use of the waters of interstate streams firmly established by the Supreme Court, the states are no longer justified in insisting upon the strict rules of Common Law, and they should be, and doubtless will be, disposed, in the future, to consider these questions in the light

of mutual convenience and necessities. What is necessary for that purpose is a comprehensive intelligent study of each problem of the allocation of the various uses of interstate waters, and a mutually beneficial arrangement between the states, or parties, interested.

POLITICAL FACTORS

No state, or watershed, should be denied the future which its natural resources will sustain.

In view of the growth of population and industry in certain sections of the country during the past century, it is difficult to accurately foretell the possibilities of any state or watershed for the coming century. The best judgment available should be applied to any problem involving the use and development of the natural water resources of an interstate stream.

That judgment should not be unduly influenced by political, sectional, or even scientific, prejudices. Sanitarians are apt to think only of sanitation; water supply engineers are apt to think only of water supply; power engineers are apt to think only of water power, and so on through all the different uses of a stream. Most technical experts think that their particular line is the most important, and therefore the primary use of water.

What is needed is a cosmopolitan agency composed of technical statesmen in each of the several uses of natural water resources, so that the result will afford the optimum of variety and extent of potential usefulness.

STATE AGENCIES

In some instances a unity of purpose in certain parts of adjacent states has been sought by the creation of a public corporation by interstate compacts. Such delegations of sovereignty and powers have resulted in a sort of super-state over which the parent states have lost control. While there is doubtless room for differences of opinion on the subject, it seems that *joint* action by the states themselves is more reasonable and responsive than action by an independent super-state created by the joint action of the states.

A large number of states have created commissions to co-operate in the solution of interstate problems. In a number of instances such commissions have made substantial progress.

While they lack compulsory powers, it seems entirely feasible and practicable that, under such leadership, the co-operative considera-

tion of an interstate problem, such as the development and conservation of the natural resources of an interstate stream, could be worked out in a manner that would reconcile differences of opinion and interest, and, through widespread discussion and consideration at public meetings by representatives of all phases and interests, (as has been undertaken by Interstate Commission on the Delaware River Basin), bring into operation an influence upon public interest and sentiment that would go far toward the promotion of joint enterprises in such fields.

In that way the usual lack of common understanding on the part of the public, the press, and the members of the legislatures could be overcome and the way paved for intelligent and prompt action after a wise plan has been developed, fully discussed and sufficiently publicized.

FEDERAL AGENCIES

The commerce clause in the federal constitution enables Congress to deal with all important interstate streams from the standpoint of navigation and water power.

In the exercise of that power the Federal Government has undertaken, through the National Resources Committee, a comprehensive study of Drainage Basin Problems and Programs. Its report of December, 1936, deals with the following objects:—

1. To determine the principle water problems in the various drainage areas of the country.

2. To outlining an integrated pattern of water development and control designed to solve those problems, and

3. To presenting specific construction projects and investigation projects as elements of the integrated pattern or plan, with priorities of importance and time.

The subjects of investigation as listed in the report are bank and coastal erosion control, domestic and industrial water supply, drainage, flood control, generation of electric power, irrigation, navigation, recreation, soil conservation and forest development, waste disposal and pollution abatement, and wild life conservation.

Such a project will reasonably require a number of years in development, but its accomplishment would be of inestimable value as a guide to both state and interstate development of stream resources.

That Committee is (or can be) better equipped with facilities and personnel than any state or interstate agency for the comprehensive

and important task of considering, balancing, apportioning and publishing the essential elements of a broad program for the conservation and development of the several uses to which the waters of a stream may be economically or practicably applied.

With respect to interstate commerce features, the federal government would be controlling. With respect to the other features, such a program would have persuasive influence toward over-coming local objections, or divisions of sentiment.

While the states may rightfully assert their independent sovereignties, and have the right, under the federal constitution, to negotiate and ratify their compacts for interstate purposes, the guidance of such a wise and impartial federal program for the development and use of each great interstate stream, for all the best, practicable and suitable, but not inconsistent, purposes for which it is available, would be of great value in leading the states into intelligent and conservative compacts for the development of those uses, in co-operation and conjunction with the federal government in the development of federal objects.

A SOLUTION

Such a federal program would furnish an ideal basis for action by co-operative state commissions of the character above described. In that way the states could exercise their sovereign rights over their domestic affairs, with the aid of intelligent federal assistance in the matters of investigations and programs.

The conflict between sentiment in favor of preserving the sovereign rights of individual states and the development of a strong central government has existed in this country since our forefathers assembled to form the first constitution. Whatever may be said for one doctrine, or the other, with respect to matters existing solely within the territorial limits of a state, experience amply demonstrates that federal co-operation and leadership, at least, is necessary to the welfare of the states in all matters touching their relations with each other.

The natural interest in the federal aspects of the amenities of a great river is of sufficient importance to prevent individual states, or groups of municipalities, bordering on such a stream from exercising their unrestricted powers, in disregard of the general welfare, for one purpose, to the exclusion of other equally valid purposes, and particularly where they have common interest in a natural resource, such

as a great river. A study of the problem before us will demonstrate to the mind of the most rigid advocate of states rights that the common interest of all the states interested in an interstate stream would be best served by the happy conjunction of a federal agency like the National Resources Committee, to investigate and plan the integrated development of the uses of such a stream and an association of state commissions to carry it out in the exercise of the sovereign powers of the several states involved.

While this combination of federal and state effort would still require compacts, ratified by the legislatures of the states, and approved by Congress, nevertheless it is competent for Congress to pass a general law ratifying in advance any compacts between states made pursuant to, or carrying out, a program promulgated by the Natural Resources Committee.

In that way a separate action of Congress in each case would be avoided.

CONCLUSION

It seems impossible to escape the conclusion, that by such a combination of effort the Federal Government would be fulfilling its highest function in respect to the subject and the states could fully exercise their independent sovereignty to the mutual advantage of all the people interested. Such an arrangement would be a vast improvement over the more or less muddling and piecemeal (and usually inadequate) methods of the past.

DISCUSSION

*Discussion by Mr. Willard T. Chevalier:** I shall attempt no formal discussion of this entire paper with all of the ramifications of the broad questions that it raises. I should like to confine my comments to one aspect of the whole subject which seems to me to be vital. I am leaving untouched many areas that are properly included in the subject of the paper.

Obviously, we are proceeding in this country to a greater and greater use of federal agencies in our social and economic life. It needs no argument to show that a very large part of the greatness of our nation has been built upon the fact of free economic and social intercourse between all of the people of the forty-eight states. Today, socially and economically, we do not think in terms of local

*Vice President, McGraw-Hill Co., New York, N. Y.

regions, states, cities, or any other political subdivision. We are a nation. When we sit down in the morning in Buffalo and eat our grapefruit from Florida or California at breakfast, and when the man in California may drive here in an automobile manufactured in Michigan, we are getting a pretty good idea of what national unity means in terms of social and economic concept.

It is also perfectly obvious that when we come to solve the problems of our natural resources, we are going to have to deal with natural regions based upon natural features. Of course, there is no more outstanding or no more significant natural feature than the great watersheds that are tributary to our principal streams. Now it will be perfectly obvious that states, as such, do not provide such natural regions. It is my judgment that we are now on the way to having the states relegated gradually but certainly to a position where the political and police powers will be about all that is left to them as far as administrative and constructive agencies are concerned. This is not a matter of political opinion. It is not a matter of choice. It seems to me it is an inevitable sequence, inevitable development in the growth of our national life. It is true, of course, that certain aspects of public improvements, such as our highways, will remain under state jurisdiction indefinitely, but even they have been developed in the present state of perfection because of the coordinating influence of the Bureau of Public Roads exercising federal power to bring about unity of road plans and of standards of design and construction.

To make perfectly clear, I said in the beginning that in what I have to say of a specific nature I have been obsessed by no such doctrine as state rights. I am limited by no narrow view of any legalistic conception in approaching the problem that has been opened up by Mr. Minard.

I should like to point out that it is exceedingly easy to draw maps of natural regions. All you need is a map, a pencil, and a knowledge of how to run out a watershed. It is also easy to lay down broad plans for organizations that will study and initiate programs and coordinate with the various public federal bureaus. These things are not difficult to do.

The question that I should like to raise is the question which, it seems to me, is basic in a discussion of this problem: How are we going to select the personnel? How are we going to secure the disinterested "technical statesmanship" to which Mr. Minard refers in

his paper and which is so lightly assumed in the various proposals that are set forth for federal coordination of this problem of allocating our natural resources. Equitable apportionment is all right as a legal concept, but who is going to determine equity, how is he going to determine equity, and how is he going to make equity stick?

Mr. Minard says, "What is necessary is a comprehensive, intelligent study of each problem of the allocation of the various uses of interstate waters and a mutually beneficial arrangement between the states or parties interested. Judgment should not be unduly influenced by political, sectional, or scientific prejudices." Splendid as a statement of objective! I now feel that we are up to the point where somebody has to write a very specific program and draw a very specific and precise plan of just how we are going to achieve these ideals that are set forth in an objective. Mr. Minard objects to the creation of public corporations by interstate compacts as "a delegation of sovereignty powers to a super-state over which parent states have lost control." I think the joint actions by the states themselves are reasonable and "responsive"—I quote that word—but it would be perfectly easy to limit any delegated powers to the matter in hand. I have a very strong conviction that responsiveness in a technical agency of that sort is not altogether a virtue. It seems to me that when a mission has been clearly defined and a competent body has been set up to deal with that mission, the less responsive they are to the political organization of a state or any other group, the more likely we are to get a solution based upon reason, fact, and science rather than political compromise and expediency. The same applies to interstate commissions.

When we get into these matters of joint interest between states and regions, the current and somewhat routine answer at once is: We should have federal action. Federal action has become the panacea by which to solve all conflicts of interest. We delegated the whole matter to the "Great White Father" in Washington, and through some Board, Commission or Committee, we are going to get an answer that will be "wise and unpartial." Now I am unable to see that there is any virtue inherent in a federal agency that does not reside in some other agency. Any federal agency is made up of human beings the same as any state or local agency. After all, the results that are accomplished are going to be in the end the result of personal interest, personal competence, personal skill, incentive, tenure of office, and all of the other human and organizational factors that go into any

kind of human effort. We have not yet learned how to breed a race of superior beings who will find exclusive employment in a federal agency that will not be equally available for any other agency that may have need for their services.

It is true that federal cooperation and leadership are necessary to solve these broad problems. I implied that I believe in a measure of federal leadership and coordination in what I said in my opening. But who is federal? How is he selected? To whom is he responsible and responsive? How long is he going to hold office and do his job before he must be up for reappointment? What incentives are going to govern his judgment of these complicated and far-reaching questions? How is he going to be protected against the vast pressure, political and private, that will be brought to bear upon him in a matter so far reaching as these subjects that are here under discussion?

Who is federal? Federal is simply a word, an adjective. It has no existence apart from the explicit agencies that are set up to operate under that name. Are we going to expect of such a federal agency, because it is a federal agency, that it be free from the pressure of an administration that might have shown prejudices on some aspects of our natural resources problems? Are we going to expect that these technicians and economists who would make this study are going to be any more free to follow out those economic and scientific convictions, than, for example, the Supreme Court justices are to follow out their legal convictions today? For a great many years, when we have talked about setting up an agency to solve these public problems, someone always has said, "What we need is an agency that will be absolutely free from political considerations and self-interest," and they always end up like the Supreme Court. Think that over for a minute!

What is it going to be like now? Now we have a group of our people telling us that the Supreme Court has seen the handwriting on the wall and has come to heel, and the next time we wave a big stick, they will be expected to do the same thing. Now I ask—how are we going to set up these new agencies? We no longer have the Supreme Court as something beyond all consideration. So now we must find a new way of setting up agencies that will be, at least to a substantial measure, free from these limitations.

Mr. Minard refers to "The happy conjunction of a federal agency like the National Resources Committee to investigate and plan the

integral development of uses of such a stream, an association of state commissions to carry it out in the exercise of sovereign powers of the several states involved." A "happy conjunction!" What insures that it will be "happy"? Why have we a right to assume that because a federal agency is superimposed that it be a "happy" solution of the problem? I am not saying it is necessarily an unhappy solution. I am simply indicating that the mere fact of a federal agency does not to me imply a happy solution. I am not at all out of accord with what Mr. Minard has stated as objectives. I go all the way, but I should like to see a discussion on this subject begin where he has left off. I should like to see an acceptance of the principles he has laid down and the objectives he has set up. I should like to have someone tell us just how we are going to do the job and how we are going to be guaranteed against the very abuses that take place in the handling of these matters by appointments. We can readily admit (1) the national character of many of our natural resource problems; (2) we can admit the regional development of drainage basins as a very desirable and necessary solution of the problem. We can admit that study and coordination of a federal agency, even the cooperation of federal agencies, to lay out rational plans is a very desirable and necessary thing provided that these federal and regional agencies are first; in every respect technically competent and representative and appointed not by the accident of a political election but appointed with the consultation, the advice and the guidance of bodies of technical men who have no interest other than the technical solution of these problems for the best interests of our economic welfare—men who will be chosen from those recommended by groups that are entirely free from any question of political allegiance or responsiveness; and second, men who will be without political identification or affiliation or responsibilities so far as the particular job on which they are concerned may have a bearing; men of sufficiently long tenure of office to insure political independence; men who will serve on these groups with a tenure of office of not less than ten years, or perhaps twenty years. I have my doubts about making it a life tenure. They might become so old the commission would have to be packed in order to preserve their independence. But at least we should have a long enough tenure so there would be no question about temporary appointment and having to come up for reappointment in a few years. Specifically, I should say that the majority of such boards and committees should cer-

tainly hold office for more than a period of two presidential terms. They should be established on a basis that will make membership attractive to the highest type of men in the profession—men to whom membership on such boards and commissions would not be just a job, to say nothing of a political job, but it would be a decoration that they would carry the rest of their professional lives with pride.

Furthermore, provision would have to be made to win public confidence for technical advisers rather than political leaders. The American people are far more responsive to political leaders than they are to technical advisers. We are going to have to breed a new type of technical administrators and a new public respect for technical authority. These, to my mind, are all part of the problem. They are matters of detail. But, gentlemen, detail is of the essence of this problem. It is easy enough to set down a broad objective, but the detail of how it is going to be carried is the very essence of the problem. There are many such problems. One might approve of marriage as an institution in the abstract, but when he comes to the detail—whom he is going to marry—it is quite important. It is a mere detail with respect to the institution but nevertheless it is certainly very important so far as the individual is concerned.

I hope I shall not be considered as flippant or lacking in appreciation of what is big, broad, or comprehensive. I hope that out of Mr. Minard's excellent statement of principle and objective, we may be able to develop something next time or before next time—because it looks as though we are going to get action right now as to some aspects of this thing—that somebody will speak in favor of setting up agencies to do this job that will be able to guarantee some improvement on what we have had, and that somebody will see to it that our objectives are pushed up in the forefront as reasons for this program and as principles that should govern them.

*Discussion by George S. Burgess:** Mr. Minard explained concisely the legal barriers that local interests have long put in the way of inter-State agreements. He indicated that the Supreme Court decisions, the highest of our tribunals, put public needs above the cobwebs of the law. He referred in abstract terms to political considerations that have to be satisfied. Finally, he expressed the belief that a federal plan and an association of state commissions to carry it out, combines the best means of developing inter-State rivers.

*Chairman, New Jersey State Water Policy Commission, Trenton, N. J.

That seems to me obviously the best means and should be accepted by everybody. Unfortunately, however, the political considerations are so many and diverse they make accord improbable. They, in turn, are reinforced by a lot of smart alecks who would propose something different from a perfect agreement, if a perfect agreement were a possibility. Someone with power and determination to conceive, adopt and carry out a plan is more likely to succeed. Which leads me to the conclusion that the Eastern seaboard States—particularly New Jersey, Pennsylvania and New York—are right in the path of federal control of waterways for water supply, flood restriction and water power purposes. Such a control has just been initiated by President Roosevelt.

New England is getting together with federal planning and federal assistance. The disastrous floods of last year precipitated their subordination of local notions and jealousies to the broader viewpoint—and money—of the Federal Government. Here, as in countless other respects throughout our nation, local helplessness has sent states rights aviating with the wind.

Coming down to the three great industrial and commercial states of the mid-Atlantic coast area—New York, New Jersey and Pennsylvania—despite a few uninitiated hopefuls—they are no farther advanced than 20 years ago in the reconciliation of their separate purposes for the future of the Delaware river.

Now let us see if this is not so. Back in 1923 a Tri-State Commission was created to draft a treaty for joint control and use of the river. This commission framed an agreement based on the principle that the interest in the river should be in proportion to the drainage area in each State. New York's legislature ratified the treaty. New York wanted water from the Catskill watershed of the river and was satisfied with the quantity such an apportionment would give her. New Jersey, with the smallest portion of the watershed of the Delaware, refused to ratify the treaty. There was a loud to-do about it both in and out of the legislature with charges that the New Jersey representatives on the commission had sold out their State. Pennsylvania let the matter ride and two years later March 21, 1925 a second Commission was created.

There was a deal of outsmarting the other fellow in the work of this second commission, resulting in a compromise predicated on doubtful engineering data. New York's legislature promptly ratified this, as it did the first, treaty. She was to be allowed to develop

660,000,000 gallons daily; Pennsylvania the same quantity; and New Jersey, 330,000,000. This was a better break for New Jersey, as one can see from the relative size of the drainage area in each State. Pennsylvania has 3,827 square miles—New York, 2,389 and New Jersey but 1,612—if you count all of the basin down as far as Philadelphia.

The second treaty went the way of the first. Trenton was in the throes of a municipal election campaign. The cry was raised that the treaty would dry up the Delaware. So the New Jersey legislature, after hearing more propaganda than facts, turned it down. Pennsylvania pursued its former course of smugness and did nothing about it.

New York then decided to go ahead anyway, despite the attitude of her neighboring States, and the consequence was the period of litigation which Mr. Minard has cited. The outcome was a decree (May 4, 1931) which permits New York to take 440,000,000 gallons daily from the Delaware, provided she makes sure that the sanitation of the river below Port Jervis is all right. New Jersey and Pennsylvania are permitted to have side-line observers to make certain that the court's decision is obeyed.

The New Jersey State Water Policy Commission has been appointed by Governor Hoffman as the accredited representative of that State. The Commission is charged with the responsibility of seeing that these conditions of the Supreme Court decree are observed:

1. That the City of New York diverts no more than 440,000,000 gallons per day.

2. Construction of an efficient sewage plant at Port Jervis, New York, for the treatment of sewage and industrial wastes from that city.

3. That water is released from one or more of the impounding reservoirs sufficient to maintain a prescribed reserve flow in the river whenever the flow at Port Jervis, or at Trenton, falls short of a stipulated quantity of water.

The Pennsylvania and New Jersey representatives are at all reasonable times to have the right to inspect dams, reservoirs and other works constructed by the City of New York; to inspect the diversion areas, the inflow, outflow and diverted flow of these areas; to inspect the meters and other apparatus installed by the City of New York; to inspect all records pertaining to inflow, outflow and diverted flow.

The decree does not fix the quantity of water permissible for the other two States to divert, but does specify that the diversion allowed shall not constitute a prior appropriation and shall not give the State of New York and the City of New York any superiority of right over New Jersey and Pennsylvania in the enjoyment and use of the Delaware River and its tributaries.

Accepting a ratio based on either the flow of the river or its drainage area, it might be implied from the court's decision that New Jersey lost rights to a daily supply of 100,000,000 gallons of water when she rejected the second treaty. This is more than the maximum possible yield of our largest present supply, known as the Wanaque. New York's claim of 600,000,000 gallons was reduced to 440,000,000.

New York is quite content with the decision. She has begun work on a huge project which will take the Delaware allotment from the Neversink river and East Branch—tributaries of the Delaware—and an additional 100,000,000 gallons daily from Rondout creek, which flows into the Hudson river. All of which relieves her from concern for the Delaware for a long time to come.

The City of Philadelphia is much in need of more and better water and has considered several proposals that would draw on the Delaware, from a new location, more than she now takes at a point just north of the City. The latest proposal concerns the upper reaches of the Lehigh river in the Pocono mountains. The Lehigh empties into the Delaware. Her proposal contemplates a taking of 480,000,000 gallons daily. Presumably New Jersey will wish to have something to say about this diversion, as she did in the case of New York. There has been consideration of the Pocono project as a joint supply for the two States. There has been a preliminary discussion of the subject between Mayor S. Davis Wilson of Philadelphia and myself, but that is as far as the matter can proceed without enabling legislation, and no one can do much about this, or any other large water supply proposal in New Jersey, under existing law.

Governor Moore recommended $39,700,000 as an expenditure for a new water supply by the Public Works Administration in 1933, but there was no board or commission in the State that could lawfully accept the money. The next year he sent a bill to the legislature to create a Water Authority in which all present water supplying agencies would be combined. The bill stayed in a Senate committee. When Governor Hoffman came on the scene in 1935 he recommended a Water Authority on different lines. The bill died in another Senate

committee. He has twice since urged action. A third series of bills was drafted after long labor, with the best legal and political advice, and presented to the 1937 Legislature. These measures gave due consideration to the objections made to previous bills but shared their fate just the same.

This recital might be elaborated and extended back over the history of water supply development in New Jersey since 1879. The story is one of repeated procrastination until a crisis occurred. The handling of the vital matter of water supply in Pennsylvania has been equally inept.

With such a background of experience, the proper development of the river through State agencies seems remote. The public of the great industrial sections of the two States has been supinely indifferent to its own welfare ever since it was graduated from pump-handle days. The press publishes a lot about water, but is nearly as impotent as an advocate as the public it serves. Municipal authorities who know a water shortage is threatened await miracles and the almost countless warnings of groups of experts like the National Resources Committee, the New Jersey Section of the American Water Works Association, Municipal Water Engineers Associations, State and District Commissions, avail nothing in the present circumstances.

There may be a regional awakening producing results through State cooperation, but the signs of the times do not point that way.

INTERNATIONAL AND INTERSTATE POLLUTION PROBLEMS*

By J. K. Hoskins

(Sr. Sanitary Engineer, U. S. Public Health Service, Cincinnati, Ohio)

Important and frequently difficult problems involving the pollution of surface waters arise wherever human populations or industrial activities concentrate. Such problems have and will continue to plague us in this country as our population and industrial centers shift and grow. They are varied in nature and complexity and confront us at every angle of our life because acceptable supplies of water constitute a prime essential for our individual, community and commercial existence and well being. It is natural then that there should be universal interest in these matters and that many avenues of approach toward their solution should have been suggested and tested. It is the purpose of this paper to summarize very briefly some of these factors.

EXTENT OF POLLUTION OF INTERNATIONAL BOUNDARY WATERS

A compilation of water pollution problems in the United States has been published recently by the National Resources Committee (1). Some general estimate of the extent and location of needed correctional measures against pollution of international waters on our side of the border may be gained from an examination of the data in the following table (see table 1) extracted from this report, in which costs of listed construction projects are grouped by regions. Omitting the problems of Lake Michigan, which is not strictly an international body of water, projects along the Canadian border recommended for immediate construction amount to about sixteen million dollars and, from the standpoint of cost, center about the Detroit area and Lake Erie. Deferred projects are estimated at an additional twenty-six million dollars with eight million dollars more for indeterminate needs. In comparison Mexican border projects total less than $400,000.

* Presented at the Buffalo Convention, June, 1937.

JURISDICTION OVER INTERNATIONAL AND BOUNDARY WATERS

The Constitution of the United States of America vests in the executive the power to make treaties with foreign nations and specifies that when such agreements are duly ratified by the Congress they

TABLE 1

Project list for correction of pollution of international boundary waters

	GROUP A IMMEDIATE		GROUP B DEFERRED	GROUP C INDETERMINATE
	Investigated	Construction	Construction	Construction
Canadian Border				
Red River of the North		2,546,000		1,440,000
Mouse Devils Lake		535,000		415,000
Rainy River, Minn	5,000	41,000		
Great Lakes				
Huron, Michigan towns			3,644,000	100,000
Saginaw, Mich	10,000			
Superior				
Minnesota towns		1,519,000		
Wisconsin towns			1,105,000	20,000
Michigan towns			1,050,000	
Erie				
Ohio, Pennsylvania and Michigan towns		10,339,000	20,526,000	1,528,000
Ontario				
New York towns		856,000	425,000	3,850,000
Lake Champlain	25,000			660,000
St. Lawrence				
New York towns		119,000		140,000
Totals, Canadian Border	40,000	15,955,000	26,755,000	8,153,000
Mexican Border				
Lower Rio Grande—Pecos		146,000		
Colorado River	25,000	222,000		
Totals, Mexican Border	25,000	368,000		

supersede all conflicting state or national laws. Such treaties, embracing the control of pollution of international and boundary waters, have been entered into with the Governments on both our northern and southern borders. Therefore, it is generally conceded that the Federal Government has supreme authority for exercising control

over the pollution of such waters. This view is expressed by the National Resources Committee (2) in the following words: "Pollution of international boundary waters, when the subject of treaty, may be brought under Federal control regardless of any question of navigability or of state police power over intrastate streams. Treaties between the United States and other countries become the supreme law of the land and the Supreme Court has held that where a valid treaty exists there can be no question as to the constitutionality of an act of Congress necessary to carry out the provisions thereof."

In the case of both the Canadian and Mexican boundary treaties, a Commission is established and maintained by the contracting parties for the consideration and reporting to their respective governments of such matters as are embraced in the agreement.

The International Joint Commission. The treaty between the United States and Great Britain relating to boundary waters and questions arising between the United States and Canada was signed at Washington, D. C., on January 11, 1909. After ratification by both Governments it was proclaimed May 13, 1910. By the terms of this treaty the two Governments agree to certain principles, among others that for dealing with the control of pollution of their boundary waters. The preliminary article states that "For the purpose of this treaty boundary waters are defined as the waters from main shore to main shore of the lakes and rivers and connecting waterways or the portions thereof along which the international boundary between the United States and the Dominion of Canada passes, including all bays, arms and inlets thereof, but not including tributary waters which in their natural channels would flow into such lakes, rivers and waterways or waters flowing from such lakes, rivers and waterways, or the waters of rivers flowing across the boundary." Article IV concludes with the statement that: "It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other." Article VIII includes the provision that: "The following order of precedence shall be observed among the various uses enumerated hereinafter for these waters and no use shall be permitted which tends materially to conflict with or restrain any other use which is given preference over it in this order of precedence:

(1) Uses for domestic and sanitary purposes,

(2) Uses for navigation, including the services of canals for the purpose of navigation,

(3) Uses for power and for irrigation purposes."

Article VII sets up a continuing organization: "The High Contracting Parties agree to establish and maintain an International Joint Commission of the United States and Canada composed of six Commissioners, three on the part of the United States appointed by the President thereof, and three on the part of the United Kingdom appointed by his Majesty on the recommendation of the Governor in Council of the Dominion of Canada." The duties and powers of the Commission are defined in the treaty. It is given jurisdiction over and required to pass upon all cases involving the use, obstruction or diversion of the boundary waters. It is authorized to examine into and report upon the facts on matters referred to it and to render decisions subject to the approval of the respective Governments. Acting under these authorities, the Commission has adopted definite rules of procedure by which questions coming under its jurisdiction are brought to its attention.

Insofar as problems relating to the control of pollution of these international waters are concerned, the International Joint Commission would, therefore, appear to have rather broad judicial and investigative powers without the need of further Federal legislation. In fact, the Commission early interested itself in the pollution of the Great Lakes waters as a result of the widespread demand for improvement shown to be necessary from the investigations conducted by the Public Health Service in 1910–12 under the direction of Dr. A. J. McLaughlin (3) (4). The question was referred to the Commission to determine at what points and to what extent the boundary waters were being polluted in contravention of the treaty and in what way such pollution might be prevented. Further inquiries were made and reported upon in 1914 and Earle B. Phelps was then engaged as a Consultant to devise plans for correcting the conditions found to exist.

The conclusions and recommendations of Professor Phelps were brought together in a comprehensive report published by the Commission (5). The engineering studies developed feasible plans of collection and disposal of polluting wastes at all important points on the three most seriously polluted connecting rivers together with cost estimates. Furthermore, the report formulated a proposed

broad general policy for the provision and maintenance of remedial works, both present and future, applicable to the international boundary waters as a whole.

The principles herein laid down for the control of pollution remain of exceptional interest. It was assumed that the pollution of boundary waters should not be permitted to exceed that which will give 500 B. coli per 100 cubic centimeters as a mean cross-sectional value. On this assumption it was concluded that "The limit of permissible bacterial pollution shall be deemed to have been exceeded when the effective dilution as hereinafter defined shall be less than 4 cubic feet per second per capita of contributing population, based upon mean river stages during the season May to September inclusive." Where this dilution was exceeded sewage treatment was recommended to be employed. Such sewage treatment in addition to reducing the bacterial content to the prescribed limit, was also to include the removal of suspended solids capable of settling to approximately the same degree as called for in the case of bacteria. The report further recommended that in all cases where sewage treatment to a specified degree was demanded, the entire contributory population should be dealt with upon the same basis of relative improvement required so that, allowing for natural purification, the net residual pollution from each community would be proportional to its population. Steamboats passing over waterworks intakes, in conforming to the rules laid down, would need to provide complete sterilization of all sewage previous to discharge. Also no garbage, city waste or other like material would be permitted to be deposited in the boundary waters or in such places as would permit their reaching these rivers.

Following the submission of this report on policies and remedial measures, the Commission held hearings at Buffalo, Detroit and Ogdensburg to ascertain the nature and extent of differences in views to the suggested corrective procedures therein laid down, and presumably before reporting to the respective governments the plans that each should execute. From this point, available records are not clear as to the nature of the action taken, but so far as known, within recent years, no further consideration has been given to these problems by the Commission.

International Boundary Commission, United States and Mexico. This Commission was created by the treaty concluded March 1, 1889, and has exclusive jurisdiction to examine and decide all differences or questions arising along the Rio Grande and Colorado rivers where

they form the boundary line between the United States and Mexico growing out of changes in the beds of, or works constructed in, these rivers. The Commission also operates 54 stream gaging stations on the watershed of the Rio Grande on both sides of the border. The American Commissioner is empowered by law to conduct technical and other investigations relating, among other things, to sewer and water systems and other designated structures crossing the international border. The Commissioner may hold meetings at any point where question may arise, summon witnesses and take testimony. If both Commissioners agree to a decision, their judgment shall be binding on both Governments unless one of them shall disapprove it within one month from the date of announcement.

In a private communication the American Commissioner states that "While this Commission has not formulated any policies for the protection of boundary waters from pollution, this is because of the relative newness and sparse population of the border country. It is realized that this question of water pollution prevention will become emphasized with an increased use of water for manufacturing, domestic purposes or irrigation."

REMEDIAL MEASURES

The border states have not been insensible to the pollutional conditions of international waters within their jurisdiction and have been engaged in preparing and executing plans for abatement measures for many years. Although this work has been materially stimulated during the past few years by grants of Federal funds for the construction of public works, the initiative has rested with the individual states. As an example, C. A. Holmquist, Director of the Division of Sanitation of the New York State Department of Health in a private communication lists a total of 24 New York towns in the Great Lakes drainage basin which either have finished or have under construction sewage treatment plants during the five year period ending January 1, 1937. The total cost of these plants exclusive of interceptors amounts to $7,721,000. Minnesota has completed studies and reported upon the pollution of the Red River of the North and has under consideration a similar activity for the Rainy river area.

Some larger lake cities have also taken practical steps to ameliorate the pollution they contribute to boundary waters. Detroit is now preparing plans for a 425 m.g.d. plant that will cost $20,000,000, and will provide sedimentation and chlorination with sludge dewatering

and incineration. These works when completed will effect definite improvement in the sanitary condition of the Detroit River and reduce materially the load on filter plants using the stream as a source of public water supply. Toledo has in operation an 80 m.g.d. sedimentation and chlorination plant (6) and Cleveland (7), "by the end of 1937 will have in operation three modern sewage treatment plants with combined capacity of some 200 million gallons per day" providing a degree of treatment that is a major step in the elimination of pollution from the shore waters of Lake Erie. Erie, Pennsylvania (8), completed a primary treatment plant in 1931, the effluent from which is conducted two miles into deep water of Lake Erie through a 72-inch concrete outfall laid below the bed of the lake. Buffalo (9) has designed a plant to consist of sedimentation tanks with mechanical sludge removal, separate sludge digestion, chlorination, dewatering and incineration of sludge and provision for chemical precipitation if later found necessary. Niagara Falls (10) has in operation a 90 m.g.d. treatment plant, consisting of fine screens of the disc type with a one inch mat of coal to function as filters and chlorination of the effluent during the summer months. Definite progress, therefore, is being made on the American side of the border to lessen the pollution of our Canadian boundary waters although as the above table indicates, much yet remains to be accomplished.

INTERSTATE WATER POLLUTION PROBLEMS

Many of our interstate water courses are seriously polluted. Pollution resulting from contributions of domestic sewage, because it is generally quite uniform in composition and amount, can be reasonably well provided for although recent tendencies to dispose of garbage through the municipal sewerage system must force a revision of our standards of sewage strength. Industrial wastes, on the other hand, vary greatly in nature, amounts and points of origin as industrial development advances. There results a progressive but irregular increase in the burden of liquid wastes which our water courses are called upon to remove. Instances of these rather rapid changes in trades waste loads are the suppression, then rehabilitation, of the fermentation industries, the sudden growth of the cellulose textile industry, the development of our mid-continental oil fields and the gradual extension of mining. Twenty years ago all tributaries of the Ohio river with the single exception of the Monongahela, were distinctly alkaline. Now the Allegheny in Pennsylvania and many of

the streams in West Virginia are acid most of the time and the acid line in the Ohio itself is being extended further down stream each year although the mine sealing program, financed largely by Federal funds, gives promise of retarding this acid encroachment. Another invasion by trade waste pollution of many of our southern streams may be expected to result from recently developed processes of manufacture of paper pulp from yellow pine which are now being placed in quantity production. This changing condition calls for continued research and experimentation to maintain disposal methods abreast of the production of new or modified liquid industrial wastes of varying complexity.

The geographical distribution of these interstate water pollution problems is quite general throughout the country but in relative numbers and intensity they are closely correlated with population density. The section lying north of the Ohio and Potomac and east of the Mississippi rivers, comprising 14 percent of the total area of the United States, contains 65 percent of the total urban population of the country. In this same section the greater number of interstate water pollution problems exist as is shown by the summary of drainage basin problems prepared by the National Resources Committee (1). Obviously, too, in these more densely populated areas more persons suffer damage from polluted streams with which they come in contact and accordingly insistence on the undertaking of remedial measures is more vocal.

ADMINSTRATIVE METHODS OF SOLVING INTERSTATE WATER POLLUTION PROBLEMS

In general the technical solution of these water pollution problems is possible though not always economically feasible. Domestic sewage certainly and most industrial wastes generally can be purified to any practical degree required. The determination of the extent of treatment to be provided, the ascertainment of the economic benefits to be derived from such improvement and particularly the agreement upon administrative procedures to be employed for the formulation and prosecution of a program of sanitation of our interstate waters present problems of major importance. The most direct administrative method of correction of such interstate problems would appear perhaps to be through action between the states involved brought in the federal Supreme Court, because this court has original jurisdiction between two or more states in such matters. This procedure

has been invoked in a number of instances, one of the most widely known perhaps being that of Missouri vs. Illinois (11) in the matter of the pollution of the Illinois and Mississippi rivers by Chicago sewage. However, as explained by the National Resources Committee (2) "The Court has stated that it will not exercise its jurisdiction except in cases of serious magnitude, clearly and fully proved. The burden of proof rests upon the complaining state to a greater degree than it does upon the plaintiff in an ordinary suit between private parties."

In general, other continuing administrative arrangements have appeared more practical and are being tried out for the control of pollution of interstate streams. It is quite widely conceded that the watershed constitutes the logical unit for such an undertaking and that the political subdivision is not always particularly suited to the purpose. The states most seriously concerned with these problems have advocated, therefore, and in some instances adopted any one of several different forms of unified administrative control.

Co-operative agreements between executive agencies of State Governments. Perhaps the most flexible arrangement for the joint action of states in matters of interstate water pollution control is for the executive officers of the proper division of the state governments concerned to enter into a co-operative agreement for the abatement of pollutional conditions each within his own jurisdiction under definitely outlined methods of procedure. Such agreements while helpful, are limited in scope and power because their continuance and efficiency carry no obligation for financial or moral support on the part of the legislatures. Several such interstate agreements are in operation, the most notable perhaps being the Ohio River Interstate Stream Conservation Agreement (12) entered into by the state health officers of Pennsylvania, Ohio, West Virginia, Kentucky, New York, Maryland, Illinois, Indiana and Tennessee. The agreement provides for co-operation in the abatement of water pollution in one state harmful to public interests in the adjacent or downstream state and establishes a board consisting of the chief engineers of the respective state health departments for devising ways and means for carrying out the letter and spirit of the contract. A similar accord was entered into by the health officers of Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania and New York and known as the "Great Lakes Drainage Basin Agreement" (13). This latter organization agreed (14) that the minimum degree of sewage treatment

within the watershed that would be recommended or approved would be efficient sedimentation and that higher degrees of treatment might be needed for the protection of the public health. An interstate commission has also been formed for the Delaware River basin (15) composed of three commissioners and a member of the planning board from each of the four states of Pennsylvania, New Jersey, New York and Delaware. The first stated objective of the Commission is to devise a program for the reduction of water pollution in the Delaware River and its tributary streams. Several additional interstate agreements such as that for the Upper Mississippi watershed and others involving two or three states have been consummated.

A more formal and rigid procedure is for the interested states to enter into a definite compact or treaty which becomes effective upon approval by the legislature of each of the signatory states and by the federal Congress. As pointed out by a Committee of the American Society of Civil Engineers (16) such compacts when once ratified are difficult to change or modify and may be practically irrevocable. The only interstate compact of this nature now in effect designed for the specific purpose of stream pollution control is the treaty between New York and New Jersey in which Connecticut is expected to join. Commissioners duly appointed by the legislatures of the interested states drafted a form of agreement setting up specific procedures for the control of pollution in the Hudson river and adjacent tidal waters in the New York metropolitan district, including the enactment of adequate state laws, establishing definite limiting sanitary standards for the waters common to the three states and providing for a continuing administrative commission. The agreement was ratified by the legislatures of New York and New Jersey, approved by Congress and thereby became valid. If this compact can be proved effective the method will doubtless be employed by other groups of states. In fact, on June 8, 1936, the President approved a Joint Resolution by the Congress (17) giving its consent to the states of Maine, New York, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, Pennsylvania, West Virginia, Kentucky, Indiana, Illinois, Tennessee and Ohio, or any two or more of them to enter into agreements for "conserving and regulating the flow, lessening flood damage, removing sources of pollution of the waters thereof or making other public improvements on any rivers or streams whose drainage basins lie within any two or more of the said states." Under this authority certain New England states propose

to join in the improvement of the sanitary condition of their interstate streams and the states bordering on the Ohio river are now in the process of formulating a compact for control of pollution of that waterway. To date the legislatures of Kentucky, Ohio, New York and West Virginia have authorized commissions to negotiate a treaty for this purpose.

Co-operative Control by the Federal Government with the States. Existing law grants no administrative jurisdiction to the Federal Government over water pollution control except in the case of oil, such powers remaining entirely with the states. There has been a growing demand that the Federal Government take a more definite interest in these matters particularly in the interstate problems, co-operate with the states in the development and administration of interstate watershed sanitation programs and contribute to their financial support. Various bills have been introduced in the Congress from time to time with this objective and in the present Congress a bill of this type—the Barkley-Vinson Bill (18)—has now passed the House. This bill if enacted into law would establish a Division of Water Pollution Control in the United States Public Health Service, would authorize co-operation with existing state agencies in comprehensive planning for correction of the pollution of waters throughout the country and would encourage co-operative activities by the several states for the prevention and abatement of pollution including the enactment of uniform state water pollution laws and the formation of compacts by groups of states for the same purpose. The bill also provides for Federal aid in the form of grants and loans for the construction of remedial treatment works by any state, municipality or other public body discharging sewage or polluting material into public waters, and loans to private corporations for the same purpose. Expenditures are also authorized for the maintenance of the Division in the Public Health Service and to the State Health Departments for a period of ten years for promoting, investigating and planning stream sanitation programs. Briefly two necessary elements would be supplied for constructive work in stream pollution control: (1) The strengthening of the state organization so as to be able to respond to public demand for adequate enforcement of state laws and regulations, and (2) the availability of Federal funds for loans and grants to states and municipalities and loans to industry for stream pollution abatement works.

Absolute Control by the Federal Government. Another type of

legislation that has received considerable support would place absolute administrative control of and responsibility for stream pollution abatement under the jurisdiction of some established federal agency. Under this plan existing state laws and responsible agencies for the control of water pollution would be entirely superseded by a law giving the federal courts jurisdiction to deal with all cases involving the pollution of waters and providing fines and punishment for all violators. Existing state jurisdictional agencies generally oppose this approach to the problem as being so drastic as to be impracticable and unenforceable.

CONCLUSIONS

The increasing pollution of our surface waters by population groups and by industry has created a general appreciation that comprehensive corrective measures must be put into effect if our surface waters are to be of maximum use. The Federal Government has evidently ample authority, not yet fully employed, for the administration of control measures so far as our international waters are concerned. The present tendency is toward more active co-operation among the states, either by informal agreement or through the agency of formal treaty, for solution of their interstate water pollution problems, and toward the enlistment of the aid of the central government in a financial and supervisory capacity in this movement.

REFERENCES

(1) Drainage Basin Problems and Programs. National Resources Committee, December, 1936.

(2) Report on Water Pollution by the Special Advisory Committee on Water Pollution. National Resources Committee, 1935.

(3) Sewage Pollution of Interstate and International Waters. I. Lake Erie and the Niagara River. By A. J. McLaughlin. Hyg. Lab. Bull. No. 77 (1911).

(4) Sewage Pollution of Interstate and International Waters. II. Lake Superior and St. Marys River. III. Lake Michigan and the Straits of Mackinac. IV. Lake Huron, St. Clair River, Lake St. Clair and the Detroit River. V. Lake Ontario and St. Lawrence River. By A. J. McLaughlin. Hyg. Lab. Bull. No. 83 (1912).

(5) Pollution of Boundary Waters. Report of the Consulting Sanitary Engineer upon Remedial Measures. March 8, 1916.

(6) Separate Sludge Digestion Plant at Toledo Mechanically Operated Throughout. By H. P. Jones. Eng. News-Rec., **106**: 389 (1931).

(7) Sewage Disposal at Cleveland. By Geo. B. Gascoigne. Ohio Conference on Sewage Treatment, Ninth Annual Report, 25 (1935).

(8) Erie Sewage Treatment Plant. Design and Preliminary Results of Operation. By A. B. CAMERON. Sew. Wks. Jour., **4**: 800 (1932).
(9) Buffalo Solves its Sewage Problem. Anon. Eng. News-Rec., **117**: 438 (1936).
(10) Coal Mat Filters and Centrifuges at Niagara Falls Sewage Plant. Anon. Eng. News-Rec., **116**: 245 (1936).
(11) State of Missouri Against State of Illinois and the Sanitary District of Chicago. U. S. Rept., **180**: 208 (1901).
(12) Board of Public Health Engineers of Ohio River Basin. By W. F. STEVENSON. Am. Jour. Pub. Health, **18**: 104 (1928).
(13) Great Lakes Drainage Basin Agreement. By LEWIS R. FINCH. Am. Jour. Pub. Health, **18**: 656 (1928).
(14) Steps to Prevent Pollution of the Public Health. Anon. Eng. News-Rec., **103**: 800 (1929).
(15) Interstate Commission for Delaware River Basin. Anon. Eng. News-Rec., **117**: 207 (1936).
(16) Interstate Water Matters. Committee Report. Trans. Am. Soc. Civ. Eng. **94**: 1400 (1930).
(17) Legislation Enabling Interstate Water Compacts. Anon. Pub. Health Rep., **51**: 820 (1936).
(18) Bills to Create a Division of Water Pollution Control in the United States Public Health Service and for Other Purposes. 75th Congress, 1st Session, S. 702 and H. R. 2711.

DISCUSSION

*Discussion by A. E. Berry, Toronto, Canada.** This discussion on Mr. Hoskin's paper will be confined to conditions on the Canadian side of the International boundary.

A first thought on this problem is that it is one both of magnitude and of long standing. The investigation of these boundary waters in 1912 was the first major step in a program directed toward correction of pollution. Since then substantial changes have been made on both sides of the border, yet the problem continues to be of major concern, and heavy expenditures will be involved to bring about a complete solution.

The problem, as far as Canada is concerned, is primarily international rather than inter-provincial. In this respect we are more fortunate than many states. Major pollution problems do not exist at present between the provinces, chiefly due to our distribution of population and the absence of watercourses on interprovincial boundaries. Furthermore, Canada has not yet reached the position of

* Chief Engineer, Provincial Department of Health, Toronto, Ont.

industrial development and concentration of population at these strategic points which prevails at many of the United States centres.

Pollution of the International waters bounding the province of Ontario is still a major problem, in spite of the efforts which have been made. This occurs chiefly on the following rivers: Rainy, St. Mary's, St. Clair, Detroit, Niagara and St. Lawrence. The width of the lake acts as an effective barrier against the transfer of pollution, except at the mouths of major streams. At the time of the former investigation the population contributing sewage on the Canadian side of these rivers as compared with now was:—

	1913	*1937*
Rainy River	3,200	7,000
St. Mary's River	15,000	23,000
St. Clair River	10,000	20,000
Detroit River	40,000	130,000
Niagara River	13,000	33,000
St. Lawrence River	44,000	64,000
Total	125,200	277,000

This 24 year interval has therefore brought an increase of over 150,000 in population.

There have been no new treatment works installed for the municipalities on these rivers during this period, but progress has been made in municipalities on the lakes.

Public Health Act of Ontario. Administrative control of water pollution in Ontario and for the most part the same in other provinces, results from the authority of the Public Health Act. The Provincial Department of Health is granted the right to examine all plans for sewers and sewage disposal, and to reject these if they do not appear to be adequate to meet local requirements. Approval of all such projects is required before work is undertaken. The Department also has authority, under the same act, to control industrial waste discharges of all kinds and to undertake investigations of waters as occasion may arise. There is also legislation making treatment compulsory if the department of health issues an order. In this act sufficient legal authority has been provided to meet pollution problems of our water courses.

Practice in Disposal in recent years. Sewage disposal practice in Ontario may well be considered as it applies to new sewerage systems, and to existing ones. For the last ten years no new systems have

been permitted to discharge untreated sewage into any of the waters of the province, irrespective of the flow in the stream. Where raw sewage has been discharged for some time into a watercourse it has been found difficult to secure expenditures for treatment unless conditions were noticeably bad, and especially has this been true with abnormal financial conditions. Popular opinion does not yet readily endorse expenditures for such projects.

Future Policy. As to the immediate practice to be followed in sewage disposal on the Canadian side, a number of factors will have a bearing. Co-operation on both sides of the border is most necessary. Canadian municipalities will not wish to lag behind in any treatment program for the reduction in pollution, nor will much be gained by any effort which is confined to one side of the border only, especially where the rivers are of insufficient width to prevent cross mixing of pollution. In fact the tardiness of the program on both sides may be partly ascribed to securing joint action where a number of parties are involved.

Stream control programs in Ontario for the immediate future include projects having a direct bearing on the International problem. Arrangements have been completed for a pollution survey of the Rainy river. This will be carried on jointly by the State of Minnesota and the Province of Ontario. It will provide data on the extent of the present pollution, as well as a comparison with that found 24 years ago. Another project involving the old Welland canal is now being advanced. The outlet of this is into lake Ontario at Port Dalhousie. This stream carries much industrial waste and domestic sewage. Detailed studies of the extent of the contamination have been made by the Ontario Department of Health, and now an engineering report dealing with remedial measures is in the course in preparation. In the large centres of population, on the lakes, rather than the rivers, there is a move, though somewhat slow, to bring about adequate treatment of sewage. No direct government grants for this purpose are available on the Canadian side, as an inducement to initiate these schemes. The cities of Toronto and Hamilton are both considering further treatment of their sewage.

It is now 24 years since the investigation of the boundary waters. Many changes in sewage treatent have taken place in that period, and opinions as to the requirements may have similarly altered. In most places the pollution is not likely to have been reduced, but probably has increased. There would therefore seem to be some benefit

to be gained by further conferences between State and Provincial administrations, not only to review some of the original conclusions but also to clarify our objectives, and to assure the maximum of cooperation on both sides of the border.

*Discussion by C. A. Holmquist.** Mr. Hoskins has covered this subject in a very comprehensive manner and I do not feel that much of interest can be added except perhaps some more details regarding New York state. The need for cooperation in the control of interstate streams has been recognized by state health departments for many years and has been reflected in various agreements that have been entered into between the state departments of health of such states as New Jersey and Pennsylvania, New York and Pennsylvania and those in the Ohio river and Great Lakes basins. Although these agreements have resulted in considerable benefit to the states involved, not only in the abatement of cases of serious pollution affecting downstream states that could not have been handled by the affected state without the cooperation of the state in which the pollution originated, but also in the exchange of data regarding developments in the treatment of sewage and industrial wastes, these agreements have no legal status nor enforceable authority and reliance has had to be placed almost entirely upon cooperation.

Certain problems like the pollution of the waters in the New York Metropolitan area seem too acute and of too great magnitude to be handled by informal agreements between state departments of health involved. In this case legislation was enacted in 1931 by the states of New York, New Jersey and Connecticut providing for a Tri-State Commission to draw up a compact for the control of future pollution and the abatement of existing pollution. After careful study of the local conditions a compact was drawn up by the three states and approved by Congress. This compact has been ratified by the states of New York and New Jersey and will become effective so far as Connecticut is concerned when that state ratifies it.

Pursuant to the provisions of this compact an interstate commission, engineering, laboratory and clerical personnel, have been appointed and the commission has been functioning since July 1, 1936. A number of hearings have been held, both in New York and New Jersey on the classification of the waters in the Interstate Sanitation

* Director, Division of Sanitation, New York State Department of Health, Albany, N. Y.

District. All of these hearings have been well attended and a great deal of interest has been shown in the subject. Strangely enough a higher degree of sewage treatment than that required by the compact has been demanded in many instances.

The interstate commission is everywhere receiving splendid cooperation from municipal officials. It is too early, however, to predict how fast the pollution of these interstate waters will be abated but it is confidently expected to be consummated within ten years and probably sooner, especially if federal aid is continued. This is not long, considering the cost of the interception and treatment of the sewage of all the municipalities in the district, which is estimated at upwards of $300,000,000.

Commissions for the drawing up of compacts for the control of pollution of the Delaware and Ohio rivers have been appointed and the state sanitary engineers of the states involved are now engaged in drawing up standards of purity of sewage effluent and the receiving waters.

As pointed out by Mr. Hoskins, considerable progress has been made in the abatement of the pollution of international waters. The sewage treatment plants under construction in Buffalo and Niagara Falls will provide for even a higher degree of treatment than that recommended by the International Joint Commission. These plants are being constructed largely for the protection of the public water supplies of Niagara Falls, Lockport and other municipalities derived from the Niagara river.

The passage by Congress of the Barkley-Vinson bill referred to by Mr. Hoskins should give impetus to the control and abatement of stream pollution and consequently gives added protection to the many public water supplies derived from surface sources in this country. So far as I know all state departments of health have endorsed this bill.

*Discussion by Samuel A. Greeley.** The paper by Mr. Hoskins is very timely because of the country-wide interest in clean waterways. Plans to increase and make permanent federal participation in sewage disposal projects have been before Congress during the last two or three sessions, and have been discussed quite widely throughout the country by engineering societies and chambers of commerce. The situation has been helped forward and crystallized by the surveys

* Consulting Engineer, Greeley and Hansen, Chicago, Illinois.

and reports of the National Resources Committee directed toward long-range planning of such construction work.

Progress in the construction of sewage disposal projects has been very considerably accelerated by the assistance of the Federal Government through the Emergency administration of Public Works. For instance, for the American shores of the Great Lakes the records of the state sanitary engineers of New York, Pennsylvania, Ohio, Michigan, Indiana, Illinois and Wisconsin show that within the near future there will be in operation fifty-one sewage treatment plants serving communities which in 1930 had a population of 5,110,000. Even before the period of federal loans and grants the work of the state sanitary engineers and the interest of the public in cleaner streams was accomplishing a steady progress toward the elimination of pollution. These efforts were stimulated in some cases by the action of the courts.

The difference of opinion between those desiring immediate elimination of pollution and those desiring the utmost economy in public expenditures of this character is one of the major items affecting progress in the construction of sewage disposal projects. A river, as a natural drainage channel, receives the discharge of the sewage of communities from human beings and industries. Towns are prone to consider the discharge of their sewage into a nearby stream as their proper right to which the advantage of cheap disposal urges long adherence. This practice is reasonable only so long as the stream or waterway can digest and assimilate the load of sewage pollution without causing uncompensated damage to riparian land owners down-stream or danger to the public health. In the early days the recognized hazard of stream pollution was limited in large measure to the effect of pollution on public water supplies, and thus standards of safety for drinking water and of safe loads on water purification plants were among the first to be given definite limits. The disastrous effects of pollution on the public health had been learned in many unfortunate cases. More recently the effect of pollution on the use of waterways for bathing and recreation, for the growing and taking of shellfish and on the creation of nuisance, has become of sufficient importance to cause the establishment of more or less tentative and often divergent standards by several state departments of health. Such standards represent the desires and needs of the public and appear to be increasing the required degree of treatment rather than otherwise.

Plans for federal participation appear to be directed toward assistance not only in the strengthening of the regulatory arms and police powers of the Government, but also toward financial assistance so as to remove in part the retarding effect of local policies for limited expenditures.

Many of the problems regarding the accomplishment of sewage disposal are illustrated in the experience of international and interstate commissions. Thus the Great Lakes Drainage Basin Agreement in 1928 stated as an indication of a standard that the minimum degree of sewage treatment which would be approved by the state departments of health shall be "efficient sedimentation." The Tri-State Treaty Commission of New York, New Jersey and Connecticut has designated two classes for the coastal waters in accordance with the intensity of their use, and has designated standards of sewage treatment for these classes of coastal waters.

An interesting example of a stream pollution problem arising from its interstate character is the St. Joseph River in Indiana and Michigan. The river is polluted in Indiana by the sewage of South Bend, Mishawaka and other communities; and in Michigan by sewage from Niles, Buchanan and Berrien Springs. It is reported that the downstream municipalities in Michigan are hesitant about proceeding with the construction of sewage treatment works until they are assured of similar progress in Indiana. Thus the action of one state department of health is bound up with the action of the department of health in another state. Joint action of the two states seems to be necessary, although there is a possibility of court action on the part of Michigan against the Indiana communities. Other such interstate stream pollution problems which are being attacked in a coöperative manner include the shoreline of Green Bay, located in both Wisconsin and Michigan, the Rock River in Wisconsin and Illinois, and the Upper Mississippi drainage area involving the states of Minnesota, Iowa, Missouri, Illinois and Wisconsin.

Early experience in this country with interstate compacts has developed in the western part of the country in connection with the use of rivers for water supply and irrigation. Thus interstate compacts regarding the quantity rather than the quality of the water have been established for the Colorado, La Plata, Pecos and the North and South Platte rivers, and still others were being negotiated in 1936. These compacts as negotiated by the adjacent states were approved by the Congress of the United States. As Mr. Hoskins has

pointed out, other compacts have been negotiated recently, chiefly among the eastern states, which are directed mainly to specific procedures for the control of pollution. Thus, while many of the actions to control the pollution of interstate streams are coöperative agreements between the state departments of health, there are now being developed interstate compacts which have the background of state and federal approval.

The experience with interstate compacts and international agreements has brought out the following points:

1. That standards of the purity of waterways are desirable and are being stated to cover the present day greater uses of waterways by many state departments of health. A coördination of such yardsticks is desirable, particularly if there is a sufficient background of epidemiological and economic experience, together with sufficient police power for their maintenance.

2. That one of the most effective measures in the accomplishment of sewage disposal projects is the recognition of them as having an element of general public interest, which is to be evidenced by participation in the cost on the part of both the federal and state governments.

These are the two necessary elements described by Mr. Hoskins as the strengthening of state organization and the making available of federal funds. The first is largely a matter of administrative policy for the country as a whole, and the second depends upon the recognition of waterways as national assets used and useful for the entire population, and thus deserving common financial support.

FLUORIDE CONTENT OF SOME WISCONSIN MUNICIPAL WATERS*

By Donovan J. De Witt, B.A. and M. Starr Nichols, Ph.D.†

The ingestion of fluorine as fluorides with the drinking water is generally accepted as the cause of chronic endemic dental fluorosis, commonly known as mottled enamel of the teeth. The literature on this subject has been adequately reviewed recently by Sanchis[1] and Scott, Kimberly, Van Horn, Ey and Waring[2] in this journal. The literature on the general topic of fluoride pharmacology, physiology and toxicology has been amply reviewed by both De Eds[3] and McClure.[4]

Fluorine is an element which is widely distributed in nature and one which occurs in considerable quantities. The element was known for about seventy years before the year 1886 when Henry Moissan[5] isolated it by electrolysis. Fluorine is a light yellow gas which can be condensed to a yellow liquid which boils at 325°F. below zero. Fluorine is the most active of all the elements and does not occur free in nature. It belongs to the halogen family of elements of which chlorine, bromine and iodine are the other members. Fluorine is always combined with other elements and usually occurs as fluorides. Calcium fluoride or fluorite, and cryolite the double salt of sodium and aluminum with fluorine are two of the naturally occurring minerals which contain large quantities of fluorine. Many other minerals contain fluorides in appreciable quantities and it has been calculated by Clarke[6a] from analyses that the earth's solid crust contains more fluorine than chlorine, or 0.10 and 0.063 percent respectively. Fluorite, calcium fluoride, CaF_2, according to Clarke[6b] "is also a common mineral in dolomites and limestones, and it is often associated with galena and zinc blende. Crystals of it are found in limestone geodes, where it has evidently been deposited from solu tion. In some cases it may have been formed by fluoride solutions

* Presented before the Wisconsin Section, October, 1936. This work was supported in part by a grant from The Wisconsin Alumni Research Foundation.

† Research Assistant and Chief Chemist, Wisconsin State Laboratory of Hygiene, University of Wisconsin, Madison, Wisconsin.

percolating through and replacing limestone. Its commonest occurrence is as a filling of veins." The solubility of fluorite in distilled water is 16 parts per million, while that of sellaite the corresponding magnesium compound is 87 parts per million. Crude rock phosphate contains from 3.0 to 4.0 percent fluorine as fluoride and the superphosphate used as a fertilizer contains up to 2.0 percent of the

TABLE 1

Waters showing fluoride in excess of 1.0 p.p.m.

CITY OR VILLAGE	WELL DRILLED	1930 POPULATION	GEOLOGICAL FORMATIONS ENCOUNTERED	DEPTH OF WELL	FLUORIDES AS F	HARDNESS AS $CaCO_3$	ALKALINITY AS $CaCO_3$	SULPHATES AS SO_4	TOTAL SOLIDS, 103°C.
Combined Locks.....		545	LS	241	1.75	320	208	188	527
De Pere.....	W	5,521	LSLS	715	2.05	280	188	72	360
	G		LSLS	840	2.05	300	174	100	418
	M		LSLS	781	2.05	280	186	92	357
	K		LSLS	?	2.05				
Green Bay.....	M	37,415	LSLS	837	2.0	215	180	47	270
	S		LSLS	930	1.88	240	234	38	291
	G		LSLS	915	2.0	245	222	36	273
	N		LSLS	865	2.0	240	192	33	248
	F		LSLS	956	2.8	220	160	110	389
Green Bay (Allouez).	New	1,500	LSLS	?	2.0				
Kaukauna.....	3	6,581	LSLS	798	1.86	970	171	815	1,461
	4		LSLS	726	1.86	620	184	481	960
	5		LSLS		1.8				
Kimberly.....		2,256	LSLS	665	1.2	450	308	122	480
Little Chute.....		2,833	LSL	421	1.85	380	240	152	475
Oconto.....	M	5,030	LSLS	639	1.56	180	92	73	280
	6		LSLS	599	1.56	180	92	74	266
Union Grove.....	1	755	LLS	660	1.0	330	252	41	356
	2		LLS	665	1.0				

Total population affected = 62,436.
L = limestone; S = sandstone.

element. Phosphate rock is used as a supplemental mineral for farm animals and as a source of phosphate in baking powder in addition to its use as a fertilizer.

During the year 1936 waters from two hundred and sixty sources from one hundred twenty-nine cities and villages in the State were analyzed. The Willard and Winter[7] method was used for the deter-

mination. At the beginning duplicate determinations were run on each water sample but the agreement was so consistent that we abandoned the duplication in order to analyze more supplies with the funds allotted. The method was modified slightly to use the Armstrong[8] suggestion as to indicator and the determination was smoothed out somewhat by conducting the titration with thorium nitrate in a 0.02 molar buffer solution of sodium mono chlor acetate - monochlor acetic acid - alcohol mixture after the publication of this modification by Hoskins and Ferris.[9] The method consists essentially of the separation of the fluoride as hydrofluosilicic acid by distillation of the solids residue from a 500 ml. sample of the water with perchloric acid, neutralizing, adding alcohol, buffer and titrating with thorium nitrate using alizarin as an indicator. From the results obtained the reagent blank was subtracted. Of these two hundred and sixty waters, twenty were found to have excessive amounts of fluorine. Table 1 shows our results on these twenty waters.

From table 1 it is seen that from analyses made up to date (January 1937) a population of 62,436 are using water containing excessive fluorides. This, however, is only about 2 percent of the total population. The fluoride-containing waters are found entirely on the eastern side of the State and nearly exclusively in the Fox River Valley. Most of the fluoride-bearing waters are from comparatively deep wells usually terminating in the upper Cambrian sandstone of the Paleozoic era. However, this finding does not necessarily incriminate this stratum because in most cases the casing of these deep wells does not extend to a depth sufficient to exclude water from other formations. Furthermore, wells extending into this Cambrian stratum in other parts of the State do not produce waters high in fluoride. The hardness, alkalinity, sulphate and solids content of these waters do not offer any clue as to source of fluorides. Likewise, the chlorides are no higher on these waters.

According to the chart of Dean and Elvove[10] 2 to 10 percent of the children who have used these waters since birth will show a moderate to severe mottled enamel defect and more than 50 percent will show at least a mild effect of the fluoride present. The cases of mottled enamel caused by concentrations of fluorine lower than 1.0 part per million and above 0.6 part per million were always classed as mild, very mild and questionable by Dean and Elvove.[10] In this class we have found, up to the present, only five waters. They were Clintonville (15th Street well) with 0.6, Kewaunee 0.7, Neenah 0.95, Cedar

Grove 0.6 and Wauwatosa's well no. 5 with 0.84 part per million. All the other waters examined, two hundred and twenty-nine in number, contained less than 0.6 part per million and the distribution with reference to amount of fluoride is given in table 2. It must be remembered that the results here given are on single analyses on water collected at one particular time and that other analyses might show some variation from these results. Dean and Elvove[10] suggest that the average monthly value for fluorine concentration be taken as the result for comparison in mottled enamel surveys.

TABLE 2

Distribution of sources of water with respect to quantity of fluoride as F

	NUMBER SOURCES
Waters containing 0.1 p.p.m. or less	73
Waters containing 0.1 p.p.m. but less than 0.2	85
Waters containing 0.2 p.p.m. but less than 0.3	46
Waters containing 0.3 p.p.m. but less than 0.4	10
Waters containing 0.4 p.p.m. but less than 0.5	16
Waters containing 0.5 p.p.m. but less than 0.6	5
Waters containing 0.6 p.p.m. but less than 1.0	5*
Waters containing 1.0 p.p.m. but less than 3.0	20†
Total municipal sources examined to date	260
Sources yet to be examined	252
Total Sources of Municipal Waters (1935)	512

* In very mild to questionable dental fluorosis range.

† In definite dental fluorosis range.

This survey covers many of the larger cities and villages scattered over the entire State but includes only about one-half of the public water sources used for public supplies. The survey is being continued this year (1937) under a N. Y. A. grant and it is hoped that most of the remaining waters can be analyzed during the ensuing year.

Wisconsin's fluorine problem does not appear to be at all alarming but in those few instances where excessive fluorides were found present, dental surveys are being made and the water supply improved. In some instances elimination of the fluoride-bearing water by casing off the offending geologic stratum seems to offer an attractive attack to the fluoride problem.

The legal liability of the municipality furnishing water containing excessive fluoride has not been decided but action by several individuals for considerable sums of money have been started at Chetopa, Kansas as reported by Blohm.[11]

With this partial survey of Wisconsin waters we are seen to have a touch of fluorides in certain sections of the State but right now it appears that our fluorine problem is very mild compared to some of the States mentioned where fluorides found in the water are considerably higher.

REFERENCES

(1) Sanchis, Joseph M. Jour. Am. Water Works Assoc., **28**: 1456 (1936).
(2) Scott, R. D., Kimberly, A. E., Van Horn, A. L., Ey, L. F. and Waring, F. H. Jour. Am. Water Works Assoc., **29**: 9–25 (1937).
(3) De Eds, Floyd. Medicine, **12**: 1 (1933).
(4) McClure, F. J. Physiolog. Reviews, **13**: 277 (1933).
(5) Mellor, J. W. *A Comprehensive Treatise on Inorganic Chemistry*, **2**: 6 (1922).
(6) Clarke, F. W. *The Data of Geochemistry*. Bul. 695, U. S. Geolog. Survey (a) p. 33 and (b) p. 585.
(7) Willard, H. H. and Winter, O. B. Jour. Ind. and Eng. Chem., Anal. Ed., **5**: 1 (1933).
(8) Armstrong, W. D. Jour. Am. Chem. Soc., **55**: 1741 (1933).
(9) Hoskins, W. M. and Ferris, C. A. Jour. Ind. and Eng. Chem., Anal. Ed., **8**: 6 (1936).
(10) Dean, H. T. and Elvove, Elias. Jour. Am. Pub. Health Assoc., **26**: 567 (1936).
(11) Blohm, A. W. Jour. Am. Water Works Assoc., **28**: 648 (1936).

FLUORIDES IN ILLINOIS WATER SUPPLIES*

By James G. Weart[1] and C. W. Klassen[2]

The primary purpose of this study has been the estimation of the fluoride content of the public water supplies of Illinois. It was expected that the water-bearing formations which supply water containing excessive amounts of fluoride could thus be determined. This is the necessary basis of a much more extensive survey of the distribution and severity of mottled enamel or endemic dental fluorosis.

This problem of mottled enamel cannot be a new one in Illinois. It has probably existed ever since our communities commenced to obtain water from deep wells. In 1928, a dentist in Minonk took a bus load of local children to a dental society meeting in Chicago, to exhibit their disfigured teeth, and to ask for advice as to treatment.

The study of this disorder has disclosed it as a new and serious public health problem (1, 2, 3). One of the main obstacles to rapid progress in its elimination has been the lack, until recently, of reliable and convenient analytical procedure for the determination of fluoride. Throughout this study, the colorimetric method of Sanchis (4) has been used. It has been found to be satisfactory for the routine examination of large numbers of samples.

Does the form or amount of fluorine we have in Illinois cause mottled enamel? I think we are quite sure of our ground when we say that it does. Studies by Dr. Dean (7) of the U. S. Public Health Service and by the staff of our own Health Department have definitely confirmed the presence of mottled enamel among the users of the public water supply at Galesburg, Monmouth, Milan, East Moline, Minonk, Odell, Kempton, Riverside, Geneva and Fairbury. Reliable reports of its presence have also come from Lansing, Aledo, Kewanee and Elmwood.

* Presented before the Illinois Section, April, 1937.

[1] Chemist, State Department of Health, Springfield, Illinois.

[2] Chief Sanitary Engineer, State Department of Health, Springfield, Illinois.

Editor's note: The use of the term fluoride in this paper assumes that the fluorine is not present in elemental but combined form. References to the amount of fluoride present are in terms of F.

The upper limit for the fluoride (F) content of an acceptable public water supply is generally conceded to be 1.0 part F per million. Dean, of the U. S. Public Health Service, has found that this or lower amounts in drinking water appear to be of no public health significance in this problem (8).

Because of individual resistance to it and because seldom more than 20 percent of the children in a community have used the water continuously the presence of the disease in a community is often overlooked.

This study has consisted of an estimation of the fluoride content of all the public water supplies of Illinois, including both ground-water and surface-water sources. In the case of ground-water sources, samples from each well now in service were examined.

The water supply situation in Illinois is illustrated in a general way on figure 1. North of the upper Illinois River, water of good quality and quantity is readily obtained from rock wells. Smaller supplies are obtained from the glacial drift. South of this area the rock dips sharply, and the water becomes highly mineralized. Heavy deposits of glacial drift, in many cases 200 feet thick, furnish most of the water in this area. Further south, particularly beyond the Wisconsin glaciation, the water in the drift becomes scant, the mineral content of the water from the rocks is reckoned in percent rather than in parts per million, and with the exception of a fringe along the rivers and some local gravel deposits, water for municipal use is obtained from streams and reservoirs.

Attention is called to the greatly increased use of water from Lake Michigan and from the Mississippi. With the development of satisfactory filtration methods, the employment of Lake Michigan water will show a continued rise.

The location of water supplies with a fluoride (F) content of 0.9 part per million or more is shown on figure 2. Those supplies with a fluoride (F) content greater than 1.5 parts per million are indicated by a dot. Analytical and geological data are given in table 1.

There are thus almost 100 communities in Illinois in which the children are exposed to the cause of mottled enamel. Many of these are small villages, but the total population is 330,000, or about 6 percent of the total population served by public water supplies. As about one-half of these 100 communities are using water containing 1.5 parts per million (F) or more, the seriousness of the problem becomes apparent. Included in the affected towns are such centers of

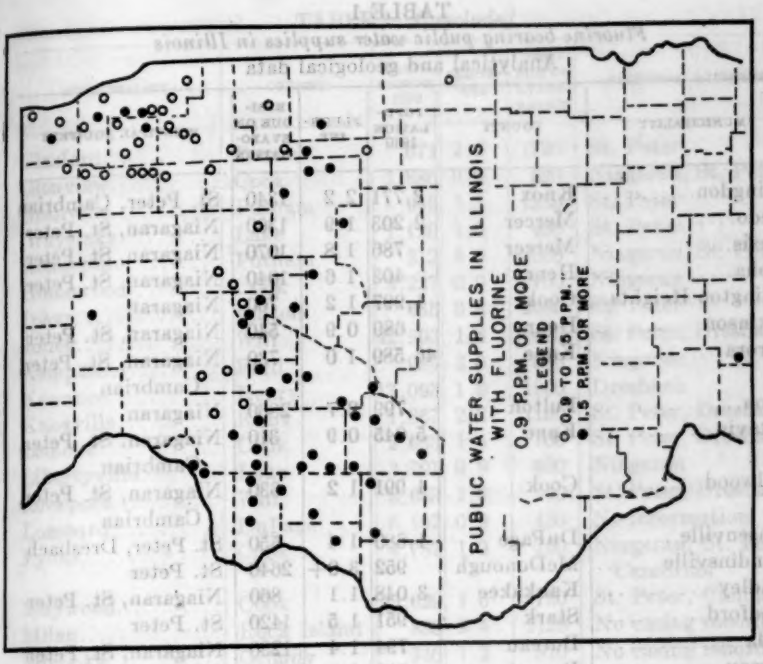

PUBLIC WATER SUPPLIES IN ILLINOIS
WITH FLUORINE
0.9 P.P.M. OR MORE
LEGEND
○ 0.9 TO 1.5 P.P.M.
● 1.5 P.P.M. OR MORE

FIG. 2.

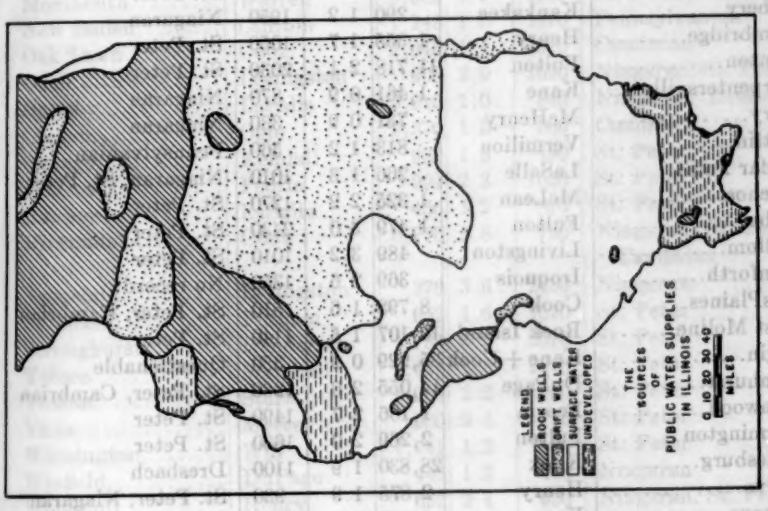

LEGEND
ROCK WELLS
DRIFT WELLS
SURFACE WATER
UNDEVELOPED
THE SOURCES OF PUBLIC WATER SUPPLIES IN ILLINOIS
0 10 20 30 40
MILES

FIG. 1

TABLE 1

Fluorine bearing public water supplies in Illinois

Analytical and geological data

MUNICIPALITY	COUNTY	POPULATION 1930	FLUORINE	RESIDUE ON EVAPORATION	PRINCIPAL AQUIFERS
Abingdon	Knox	2,771	2.2	1340	St. Peter, Cambrian
Aledo	Mercer	2,203	1.9	1300	Niagaran, St. Peter
Alexis	Mercer	786	1.8	1070	Niagaran, St. Peter
Alpha	Henry	403	1.6	1040	Niagaran, St. Peter
Arlington Heights	Cook	4,997	1.2	760	Niagaran
Atkinson	Henry	689	0.9	540	Niagaran, St. Peter
Aurora	Kane	46,589	1.0	730	Niagaran, St. Peter, Cambrian
Avon	Fulton	799	2.7	2860	Niagaran
Batavia	Kane	5,045	0.9	310	Niagaran, St. Peter, Cambrian
Bellwood	Cook	4,991	1.2	630	Niagaran, St. Peter, Cambrian
Bensenville	DuPage	1,680	1.4	550	St. Peter, Dresbach
Blandinsville	McDonough	952	3.0+	2640	St. Peter
Bradley	Kankakee	3,048	1.1	860	Niagaran, St. Peter
Bradford	Stark	951	1.5	1420	St. Peter
Buda	Bureau	794	1.4	1230	Niagaran, St. Peter
Bureau	Bureau	552	2.5	2030	Pennsylvanian
Bushnell	McDonough	2,850	4.0	1920	St. Peter
Cabery	Kankakee	290	1.2	1950	Niagaran
Cambridge	Henry	1,355	1.7	1050	St. Peter
Canton	Fulton	11,718	2.1	2030	St. Peter
Carpentersville	Kane	1,461	0.9	870	Niagaran
Cary	McHenry	731	0.9	330	Niagaran
Catlin	Vermilion	813	1.2	560	Pennsylvanian
Cedar Point	LaSalle	266	1.3	1010	Niagaran, St. Peter
Chenoa	McLean	1,325	2.2	1270	St. Peter
Cuba	Fulton	1,479	3.0	2430	St. Peter
Cullom	Livingston	489	3.2	1010	St. Peter
Danforth	Iroquois	369	2.6	1350	No record
DesPlaines	Cook	8,798	1.6	510	St. Peter, Cambrian
East Moline	Rock Island	10,107	1.5	1140	St. Peter
Elgin	Kane + Cook	35,929	0.9	350	Questionable
Elmhurst	DuPage	14,055	2.0	1260	St. Peter, Cambrian
Elmwood	Peoria	1,166	2.7	1490	St. Peter
Farmington	Fulton	2,269	2.0	1630	St. Peter
Galesburg	Knox	28,830	1.9	1100	Dresbach
Galva	Henry	2,875	1.9	930	St. Peter, Niagaran
Geneva	Kane	4,607	1.0	350	Niagaran, St. Peter, Cambrian

TABLE 1—*Concluded*

MUNICIPALITY	COUNTY	POPULATION 1930	FLUORINE	RESIDUE ON EVAPORATION	PRINCIPAL AQUIFERS
Glasford	Peoria	671	2.8	1720	St. Peter
Glenview	Cook	1,886	0.9	520	Niagaran, St. Peter
Granville	Putnam	949	1.1	1280	St. Peter
Grayslake	Lake	1,120	1.5	430	St. Peter
Hennepin	Putnam	312	3.0	2860	Niagaran, St. Peter
Homewood	Cook	3,227	0.9	700	Niagaran
Ipava	Fulton	635	3.8	2980	St. Peter
Joliet	Will	42,993	1.4	470	St. Peter, Dresbach
Kempton	Ford	289	3.0	880	Niagaran
Kewanee	Henry	17,093	1.0	1900	Dresbach
Knoxville	Knox	1,867	2.2	1150	St. Peter, Dresbach
Lemont	Cook	2,583	1.4	700	St. Peter, Dresbach
Libertyville	Lake	3,791	0.9	650	Niagaran
Lockport	Will	3,383	1.3	440	St. Peter, Dresbach
Lombard	DuPage	6,197	0.9	430	No information
Lyons	Cook	4,787	1.0	750	Niagaran, St. Peter, Cambrian
Maywood	Cook	25,829	1.6	790	St. Peter, Cambrian
Milan	Rock Island	888	2.4	1120	No casing record
Minooka	Grundy	346	1.3	810	No casing record
Minonk	Woodford	1,910	2.2	1680	Niagaran, St. Peter
Monmouth	Warren	8,666	1.7	1050	St. Peter, Cambrian
New Baden	Clinton	1,243	1.6	1370	Pennsylvanian
Oak Lawn	Cook	2,045	1.1	1370	Cambrian
Odell	Livingston	908	2.9	1670	Niagaran, St. Peter
Oglesby	LaSalle	3,910	1.0	840	Niagaran, Dresbach
Oregon	Ogle	2,376	1.5	300	Cambrian
Oswego	Kendall	932	1.3	480	St. Peter
Princeville	Peoria	994	2.3	1630	St. Peter
Ransom	LaSalle	456	1.2	870	St. Peter
Riverside	Cook	6,770	1.8	780	Niagaran, St. Peter, Cambrian
Saunemin	Livingston	376	3.6	2480	Niagaran
Standard	Putnam	352	1.6	1070	St. Peter
Stronghurst	Henderson	734	3.2	2570	St. Peter
Toluca	Marshall	1,413	1.5	2210	St. Peter
Toulon	Stark	1,203	2.2	1150	St. Peter
Viola	Mercer	566	2.4	1120	St. Peter
Wilmington	Will	1,741	1.2	1150	St. Peter
Winfield	DuPage	445	1.2	690	Niagaran
Woodhull	Henry	557	2.4	920	Niagaran, St. Peter
Wyoming	Stark	1,408	1.8	1140	St. Peter
Zion	Lake	5,991	1.2	450	Niagaran, St. Peter

population as Galesburg, Joliet, Monmouth, Riverside, Elmhurst, Maywood and Bushnell.

There is nothing astonishing about these findings. In the half-mile crust of the earth, (and some of our wells penetrate the first quarter mile), fluorine is fully half as abundant as chlorine (5). In the list of elements arranged in the order of their estimated abundance in this half-mile crust, fluorine is placed 20th, and chlorine is placed 12th on the list. It is present chiefly in the minerals fluorspar and cryolite, but is also found in many silicate minerals.

All mineral waters contain fluoride, with the proportion greatest in the waters of volcanic origin. As a rule, mineral waters of the same kind show an increase of fluoride accompanying a rise in the total salts (6). All of the waters shown on this map (figure 2) are highly mineralized. The total mineral content of those waters with a fluoride (F) content in excess of 1.5 parts per million averages 1500 parts per million, and is 770 parts per million for those supplies where the fluoride is between 0.9 and 1.5 parts F per million. By way of contrast, the mineral content of the water from 36 Niagaran wells with low fluoride, is only 500, and that from 15 St. Peter wells with low fluoride is less than 400 parts per million. There are of course exceptions to every rule.

To the water-works profession, a knowledge of the water-bearing formations from which this fluoride-bearing water is obtained should be of value. The rock formations which are the principal aquifers in Illinois are shown in a general manner in figure 3. The Silurian formations are not found in all parts of the state, but the St. Peter, the Dresbach, and the Mt. Simon sandstones underlie practically all of the northern half of the state, and furnish much of the water used by municipalities and industry.

In the past, many municipalities, in their search for water, have not been too particular as to mineral quality. In the development of a well, it was usual to cast out only such formations as presented trouble from caving, or where the water was obviously of undesirable mineral content, such as salty water or sulphurous water. As a result, many of our municipal wells obtain water from two or more formations, and a positive correlation between the formations and the fluoride content of the water could not be made. In other cases, there is little or no information either on the depth of the well or on the casing record.

The spot maps shown, however, are based upon definite informa-

tion, obtained from our own records and also through the courtesy of the State Geological Survey and the State Water Survey.

The location of wells which obtain water from the upper limestone, or Silurian formation, are shown on figure 4 by a circle. The fluoride content is indicated by the extent of the shading. Much of this water, is of course, of the same mineral content as the water in the drift above it, and the fluoride content is quite low.

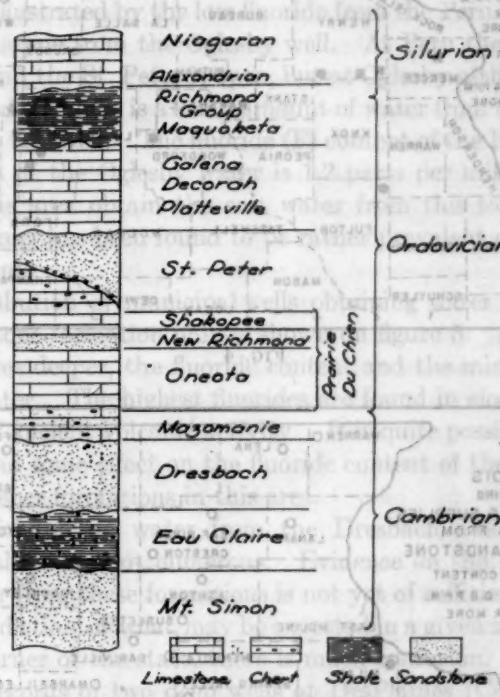


FIG. 3. DIAGRAMMATIC COLUMNAR SECTION OF N. E. ILLINOIS SHOWING STRATA. (THWAITES' CORRELATION, 1927)

In the panhandle of Ford county, where there is an increase in the fluoride content, very soft water is obtained from the limestone deposits in the Maquoketa shale. This soft water probably results from a base-exchange action of glauconite found in this formation. The fluoride (F) content of the water in this area is from 3.0 to 6.0 parts per million, and it is in this area also that the most severe mottled enamel condition is found. Water showing the effect of this natural softening is found for a considerable distance to the west, where it

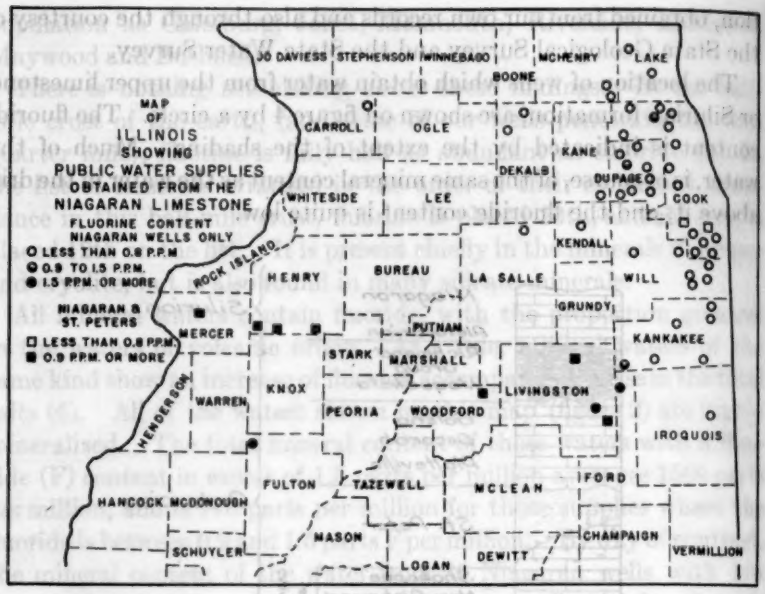

MAP OF ILLINOIS SHOWING PUBLIC WATER SUPPLIES OBTAINED FROM THE NIAGARAN LIMESTONE
FLUORINE CONTENT NIAGARAN WELLS ONLY
LESS THAN 0.8 P.P.M
0.9 TO 1.5 P.P.M.
1.5 P.P.M. OR MORE
NIAGARAN & ST. PETERS
LESS THAN 0.8 P.P.M.
0.9 P.P.M. OR MORE
JO DAVIESS
STEPHENSON
WINNEBAGO
MCHENRY
LAKE
BOONE
CARROLL
OGLE
KANE
DEKALB
DUPAGE
COOK
WHITESIDE
LEE
KENDALL
ROCK ISLAND
HENRY
BUREAU
LA SALLE
WILL
GRUNDY
PUTNAM
KANKAKEE
MERCER
STARK
MARSHALL
HENDERSON
KNOX
LIVINGSTON
WARREN
PEORIA
WOODFORD
IROQUOIS
FULTON
TAZEWELL
MCLEAN
FORD
HANCOCK
MCDONOUGH
MASON
CHAMPAIGN
SCHUYLER
LOGAN
DEWITT
VERMILLION

FIG. 4

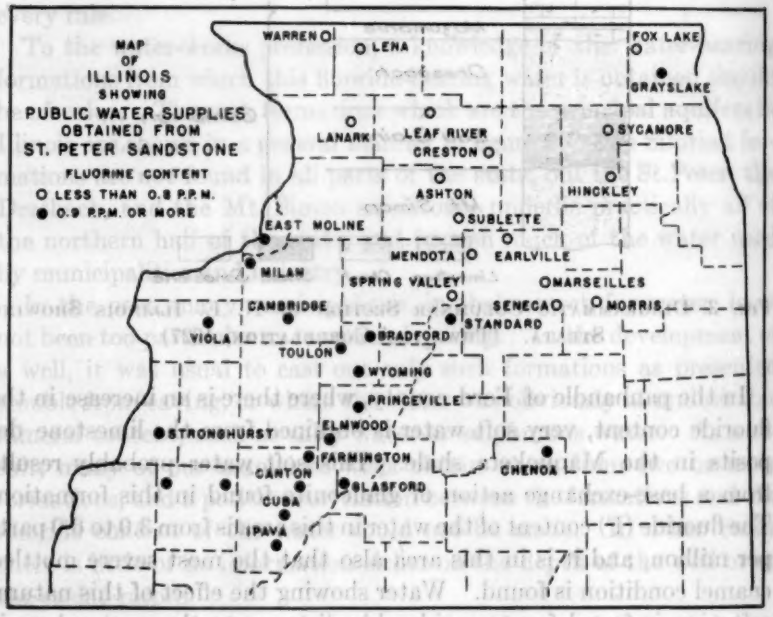

MAP OF ILLINOIS SHOWING PUBLIC WATER SUPPLIES OBTAINED FROM ST. PETER SANDSTONE
FLUORINE CONTENT
LESS THAN 0.8 P.P.M.
0.9 P.P.M. OR MORE
WARREN
LENA
FOX LAKE
GRAYSLAKE
LANARK
LEAF RIVER
CRESTON
SYCAMORE
ASHTON
HINCKLEY
SUBLETTE
EAST MOLINE
MENDOTA
EARLVILLE
MILAN
SPRING VALLEY
MARSEILLES
CAMBRIDGE
SENECA
MORRIS
STANDARD
VIOLA
BRADFORD
TOULON
WYOMING
PRINCEVILLE
ELMWOOD
STRONGHURST
FARMINGTON
CANTON
GLASFORD
CHENOA
CUBA
IPAVA

FIG. 5

is probably due to percolation through glacial deposits of this same material. As the Maquoketa shale was eroded by glaciers, this material was distributed over an area to the west. Other supplies that obtain most of their water from the upper limestone show the effect of this softening and also have a high fluoride content. These are indicated on the map by squares. East of this area neither soft water nor fluorides are found.

That the fluoride does not come from the St. Peter sandstone in this area is illustrated by the low fluoride from the Peru well, and the moderate fluoride from the Oglesby well. At Peru the Niagaran is cased out, and the St. Peter is open, but at Oglesby although the St. Peter is cased off, there is a small amount of water from the Niagaran which enters this well. The fluoride (F) content of the Peru water is 0.3 but that of the Oglesby water is 1.2 parts per million. Many farms in this area obtain the soft water from this formation, and mottled enamel has been found to be rather prevalent among many of the residents.

The distribution of municipal wells obtaining water from the St. Peter sandstone formation only is shown on figure 5. As the sandstone becomes deeper, the fluoride content and the mineral content become greater. The highest fluorides are found in close proximity to an area of ancient volcanic activity. It is quite possible that this may have had some effect on the fluoride content of the water from all of the deeper formations in this area.

Wells which obtain water from the Dresbach and Mt. Simon sandstones alone are not numerous. Evidence on the fluoride content of water from these formations is not yet of sufficient volume to enable a prediction of what may be expected in a given area. In the northeast corner of the state, there is much confusion. A study of the casing records of two deep wells at DesPlaines (Cook County) points to the St. Peter formation as the fluoride-bearing rock. At Elmhurst, a few miles further south, the one St. Peter well has a low fluoride content, and the deeper formations penetrated by three other wells are implicated. Along the Fox River valley our findings were equally confusing

There are thus three areas in the state where the menace of endemic mottled enamel may be expected. Any wells obtaining water from the St. Peter sandstone or from lower formations in the Chicago area or in the west central area should be regarded with suspicion. The Ford County area and that immediately to the west are also definitely affected.

It is the problem of the water-works profession to devise means whereby these communities may be assured that the water they drink will not cause this positive and permanent disfigurement of the teeth of the coming generations.

Let us look at the possibilities. For those localities where no other water is obtainable, some process for the removal of fluoride would be of great value. One difficulty in the removal of fluoride from water is the relatively small amount with which we have to work.

The removal or the reduction of the fluoride content of water is reported to be accomplished by chemical means through the use of alum as a coagulant (9), or in connection with the removal of magnesium in a standard water softening process (10). Several filtration or absorption methods have been proposed. Activated carbon will remove fluoride if the pH is more acid than 3.0 (11). A contact filter of sand and powdered aluminum has also been used (12). Promising results are also reported with the use of activated alumina, a product which may be regenerated and re-used (13, 14).

The possibility of the reduction of fluoride by softening treatment is discouraging when the high mineral content of water is considered. The apparent success of both the alum treatment and the activated alumina must be taken with a grain of salt unless the fluoride in the filter effluent is determined by a distillation process in order to remove the possible interfering action of any aluminum or other substance which might have been picked up by the water in passage through the filter.

Under Illinois conditions, an obvious remedy is substituting for the old, a new supply free from toxic amounts of fluorides. In some areas substitution may be impossible for there may be no other water obtainable. If a completely new supply is not obtainable, there are many cases where smaller quantities of fluoride-free water can be found to serve as a dilution for the high-fluoride water. A specific example of this possibility will be found at Galesburg where a considerable amount of water can be obtained from shallow wells in the bottom land within the city. Water from the nearby lake is also available although at somewhat greater expense. At Bushnell, ample water for dilution could be obtained from gravel packed wells in the creek bottom a short distance from the city. At Chenoa there are drift wells at the canning factory on the edge of town which supplied the entire water requirements of the village prior to 1911. At other points the water from two or more wells now in service could be mixed.

Already there has been some of this type of substitution although the urge has come from the desire to obtain better domestic water or to lower operating costs. The extension of the use of Lake Michigan water has been noted and this may be expected to continue. Towns that have abandoned a highly mineralized and fluoride-bearing water are Forest Park, Lansing, Roseville and Fairbury. This latter town went one step forward and installed a modern softening plant.

To sum up: A survey of the fluoride content of the public water supplies in Illinois, and of the areas where mottled enamel is endemic, has indicated a new public health problem of major importance. The solution of that problem is a challenge to the water-works profession.

The authors wish to acknowledge the valuable assistance of Mr. L. E. Workman, Associate Geologist, Subsurface Division, Illinois State Geological Survey, and of Dr. C. F. Deatherage, Chief of the Division of Dental Health Instruction, Illinois Department of Public Health.

REFERENCES

1. McKay, F. S. Do water supplies cause defects in teeth enamel? Water Works Eng., **79**: 1321 (1926).
2. Kempf, G. A., and McKay, F. S. Mottled enamel in a segregated population. Public Health Reports, **45**: 2923 (1930).
3. Smith, M. C., Lantz, E. M., and Smith, H. V. The cause of mottled enamel, a defect of human teeth. Univ. of Ariz., Agri. Exper. Sta., Tech. Bull. 32 (1931).
4. Sanchis, J. M. Methods of testing and significance of fluorine and fluorides in water supplies. Jour. A. W. W. A., **28**: 1456 (1936).
5. Clark, F. W. *The data of geochemistry.* U. S. Geological Survey, Bul. 695. Washington (1916) p. 34.
6. Mellor, J. W. *A comprehensive treatise on inorganic and theoretical chemistry*, London (1922), **2**: 2.
7. Dean, H. T. Distribution of mottled enamel in the United States. Public Health Reports, **48**: 712 (1933).
8. Dean, H. T., and Elvove, Elias. Studies on the minimal threshold of the dental sign of chronic endemic fluorosis (mottled enamel). Public Health Reports, **50**: 1719 (1935).
9. Boruff, C. S. Removal of fluorides from drinking waters. Ind. Eng. Chem., **26**: 69 (1934).
10. Scott, R. D. et al. Fluoride in Ohio water supplies—its effect, occurrence and reduction. J. Am. Water Works Assoc., **29**: 9 (1937).
11. McKee, R. H., and Johnston, W. S. Removal of fluorides from drinking water. Ind. Eng. Chem., **26**: 849 (1934).

12. KRAMER, S. P. The removal of fluorides from water by sand filtration. Science, 80: 593 (1934).
13. FINK, G. J., AND LINDSAY, F. K. Activated alumina for removing fluorides from drinking water. Ind. Eng. Chem., 28: 947 (1936).
14. SWOPE, GLADYS H., AND HESS, R. H. Removal of fluorides from natural waters by Defluorite. Ind. Eng. Chem., 29: 424 (1937).

DISCUSSION

*(Discussion by L. E. Workman)** Mr. Weart has shown that the amount of fluorides in Illinois ground water supplies generally increases southward with the increase in total mineral content of the waters. The southward increase of total mineral content is due to the fact that surface waters entering the formations in Wisconsin and northern Illinois and moving southward in the formations dissolve some of the rock, and also become more or less mixed with the highly mineralized water that was originally contained in the rock when the sediments were laid down. As more water is removed from the rock formations to the south, the mineral content of the waters and, at the same time, the fluoride content, should decrease, but the decrease is likely to take place so slowly that cities now using fluoride-bearing waters cannot expect to benefit by it.

Some exceptions to the general rule of the occurrence of large amounts of fluoride with waters of high mineral content were noted. The sporadic occurrence of waters having high fluoride content at Des Plaines and Oregon is explainable in each case by the local geologic structure. Each is situated in a region of local uplift and faulting where deep-seated igneous activity in the geologic past may have contributed the fluorine. The source of the fluorides at the present time may be (1) crystalline fluorite in veins or disseminations in the upper strata in the local region, or (2) mixture of upper waters normally having low fluoride content with fluoride-bearing waters rising from greater depths along fractured zones.

Likewise, the especially high fluoride content of waters in western Illinois may be ascribed to the proximity of a broad domal uplift and introduction of fluorite into the overlying strata from deep-seated igneous material. In Hancock and Adams counties, where the uplift is greatest, hardly a set of sample well cuttings is free from crystal-

* Associate Geologist, Subsurface Division, Illinois State Geological Survey Urbana, Illinois.

line fluorite, occurring as vein deposits or disseminations away from veins in the limestones.

In some localities, ground water to replace or dilute the present supplies may be obtained from sand and gravel deposits of the glacial drift within reasonable distance from the municipalities. The State Geological Survey, in cooperation with the State Water Survey, can assist in the search for such water-bearing deposits by a review of geologic data in its files, by collecting such data in the field, and by conducting an electrical earth resistivity survey. In the method last mentioned, advantage is taken of the fact that sand and gravel deposits are more resistant to the passage of an electric current than is glacial clay. By systematically testing the earth for its resistivity in the vicinity of the proposed ground water supply development, the location, depth, and extent of a subsurface sand and gravel deposit may be determined roughly and the most likely locations for test drilling be selected.

(*Discussion by J. A. Holmes**) Mr. Weart has mentioned the unsuccessful effort for the chemical removal of fluorides from water. Sometime back a paper was presented at Kansas City on the use of activated alumina for adsorbing and removing fluorides from water. This method is partially successful, but not enough so to be commercially feasible. Recently the use of tri-calcium phosphate has been tried and the results are promising. The material is simply used as a filtering medium, and after the adsorptive properties of the tri-calcium phosphate are used up it is regenerated with caustic soda and washed with hydrochloric acid. In this study it is estimated that the fluoride could be removed at a cost of somewhere in the neighborhood of 2 or 2½ cents per 1,000 gallons of 5 parts per million fluoride content. The average fluoride content in the effluent from this filter would be in the neighborhood of 0.5 parts per million or less with the material regenerated as soon as the effluent reaches 1 part per million fluoride content.

Experimental work on this method of removing fluoride is still in the early stages. It is imperative that, where it is impossible to change the source of water supply, some method of treatment must be devised. It is reasonable to assume that, if we can find materials which will adsorb and remove fluoride from water, improvements can be made on these materials so that eventually an economical and satisfactory treatment may be developed.

* Director of Service, National Aluminate Corporation, Chicago, Illinois.

(*Discussion by Dr. C. F. Deatherage.**) I am happy to speak to you as a dentist. Dr. H. T. Dean of the U. S. Public Health Service has, as Mr. Weart told you in his paper, been making quite a study of this problem, and has been in Illinois several times. We have known for several years that there were spots in Illinois that were as bad as anywhere in the country, but we didn't realize until Mr. Klassen and Mr. Weart started these analyses of public water supplies that it was so prevalent.

It is a public health problem and we have to face it. Now men, don't go home and be afraid of drinking water with fluoride in it. Your teeth are developed. But the constant use of such water by babies and young children produces serious damage. One disadvantage in this study is that we have to wait until the child reaches six, eight, or ten years of age before we can see the bad results; and when the water supply is changed, we then will have to wait five, six, or perhaps seven years to see what the change is going to do.

In the fall I hope we can make a complete survey of our state and then next year report on the findings. In this study we can only use children who have lived in the town all their life and have drunk the public water supply their entire life. In some communities only about ten percent of the children show a continual residence and then only about twenty percent of these children may show mottling on their teeth. That is the reason the disease is overlooked, except for the areas where it is very, very prevalent.

* Chief, Division of Dental Health Education, Illinois State Department of Health, Springfield, Illinois.

TAP STERILIZER FOR WATER SAMPLE COLLECTION*

By Carl Leipold

(Sup't. Water Filtration Plant, Winnetka, Illinois)

To collect samples from water taps in the field or in buildings for the purpose of checking the sanitary quality of the water supply, it is necessary first to flame or sterilize the tap outlet in order to obtain a representative sample. Erroneous opinion of the water supply can result by the collection of a water sample from a tap which is surrounded by and exposed to unsanitary conditions if the sample is collected without first flaming the tap outlet.

The writers experience with water sample collections at dairy farms, milk plants, country estates, camps, and food handling establishments, has shown that many unfavorable conditions can exist at the water tap, such as the presence of polishing compound, cloth shreds, dirt, and decayed food. Consideration should also be given to the personal contacts with water taps.

Use of the flame from matches has proven unsatisfactory at taps which do not have a tight seat and disc, also taps that are at locations subject to wind currents which cause match flame to go-out before sterilization of the tap has been accomplished. The match flame does not reach as far into the tap as is necessary and also the burning period is too short for proper sterilization at some installations.

Experiments made with various types of burners, showed that the tap sterilizer (figure No. 1) was most appropriate for tap sterilization, requiring the least amount of attention of any for rapid operation and also having an effective flame. The tap sterilizer consists of a rustproof, relief ball bearing, paper clip, size No. 10, mounted on a $\frac{1}{4}$ inch by 12 inch long steel rod. Sterilization of the taps in buildings or in the field, is done with a piece of cotton (size governed by tap conditions and wind currents) placed in the clip and then dipped into a container of denatured alcohol, gasoline, or kerosene. Denatured alcohol is preferred as it leaves no black smudge on the nickel or chromium finished taps. The alcohol soaked cotton is ignited and after the flaming of the tap is completed the tap is

*Contributed.

turned-on; permitting water to flow a sufficient period before water sample is collected for analysis. The burning cotton is extinguished by placing in the water flowing from the tap.

It is sometimes necessary to check the sanitary conditions at the tap for a twofold purpose, that of the actual sanitary condition of the

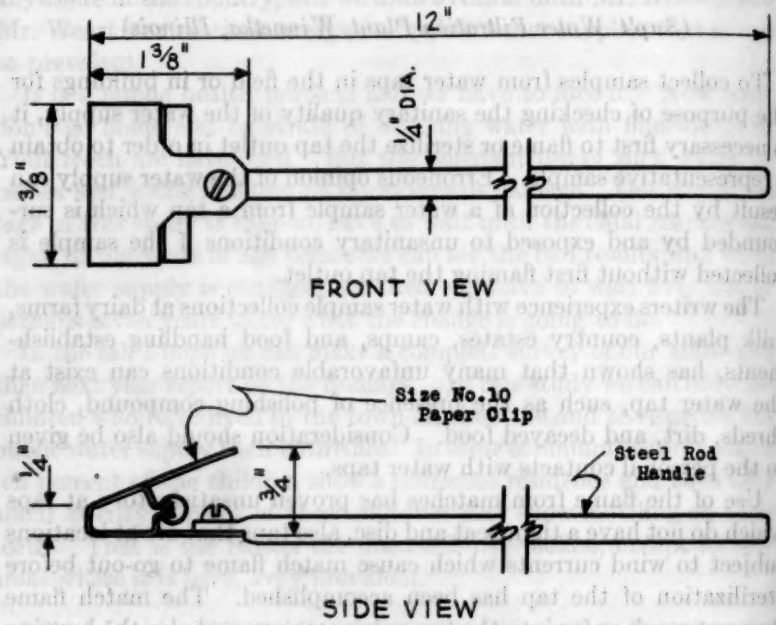


FIG. 1. TAP STERILIZER

tap and that of the sanitary quality of the water supply. For checking the tap condition, the first flow of water from the tap is collected for analysis. For checking the water, the tap sterilizer serves the purpose in eliminating unsatisfactory tap conditions for sample collection.

THE POTASSIUM PALMITATE TEST FOR HARDNESS*

By Max Suter

(Engineer, State Water Survey, Urbana, Illinois)

The increased interest in soft water and the rapid growth in the use of water softeners, both municipal and residential, requires the availability of a rapid and accurate test for the determination of the hardness of a water.

The eighth edition of the Standard Methods for the Examination of Water and Sewage gives three methods for the determination of the hardness in water. The most accurate method of ascertaining total hardness is to compute it from the results of determination of calcium and magnesium in the sample. Total hardness as $CaCO_3$ = 2.495 Ca + 4.115 Mg. The determination of hardness by the soap method roughly approximates the amount of calcium and magnesium in water, though it actually measures the soap consuming power of the water. Non carbonate hardness can be determined by the soda reagent, and this reagent allows an estimate of the total hardness when used in combination with the alkalinity test.

The first of these methods requires time (at least one day) and cannot be used when an immediate answer is needed, as in the case of adjusting the chemical dosage for softening to rapid changes in the character of the raw water. The two other methods are inaccurate and even very unreliable with certain kinds of water.

At present therefore we do not have a test for the determination of the hardness in water that is rapid and at the same time sufficiently accurate to be used in the control of water softening plants. We felt this lack of such a test in our researches on water softening. Even the committee of the Standard Methods is aware of this shortage of a good rapid test, as its report of Committee No. 1 in volume 22 of the Journal of the American Water Works Association, page 242 (1930) shows in its recommendations No. 23 on page 260, which reads: "continued search should be made for a rapid method for the detection of magnesium and calcium, preferably by colorimetric

* Presented before the Illinois Section, April, 1937.

methods, which will be sufficiently accurate for purposes of ordinary mineral analysis and which will offer advantages in time and equipment to be used in the determination of calcium and magnesium in the routine of water softening plants."

For the present we did not attempt to fulfill all these requirements, but we wanted a good and rapid rest for the total hardness. A search in the literature showed that there is in Europe a test in use for which such properties are claimed. It is known as Blacher's method for the determination of hardness, and was first introduced by C. Blacher in 1913 (1). This test uses potassium palmitate, one of the chemical constituents of soaps, as the titrating reagent. Briefly the test may be described as follows: The sample is slightly acidified to methyl orange, the CO_2 is expelled from it and then it is carefully neutralized to phenolphthalein. A tenth normal alcoholic solution of potassium palmitate is then titrated into the prepared sample. The potassium palmitate precipitates the calcium and magnesium and when these hardness forming metals are all out of the solution, any excess of potassium palmitate hydrolyzes to give an alkaline reaction with phenolphthalein. A red color of the solution indicates the end-point of the titration.

This test has received considerable study in Germany and lately some in Great Britain and France. It was found that when the test is used as a field test during cold weather, potassium palmitate precipitates out of the reagent. To avoid this, glycerine was added to the alcohol. Winkler (2) recommended the use of propyl alcohol instead of ethyl alcohol for this purpose. Pflanz (3) found that the palmitate has to be free of stearates to be stable. It is probable that some coagulation occurs otherwise.

Practically all foreign experimenters use a one-tenth normal potassium palmitate solution in which 1 ml. corresponds to 2.8 German degrees of hardness (1 part CaO in 100,000) or 50 p.p.m. expressed as $CaCO_3$. To avoid the calculation necessary with this solution, Kurt Nöthlich (4) uses a N/28 potassium palmitate solution. Also most of the foreign reports require that the potassium palmitate solution be prepared from palmitic acid neutralized with potassium hydroxide. Ohmüller-Spitta (5) following Habrich (6) recommends the direct use of commercially available pure potassium palmitate. In the amount of glycerine used in the solution there is a wide variation in the different publications, some do not use any at all, others recommend 25 to 40 per cent by volume.

Preliminary tests made in our laboratory mainly following the description as given by Werescagin (7) showed that Blacher's method has possibilities for a satisfactory rapid test. Yet some special considerations suggested some changes.

In America we use as unit of the measurement of the hardness parts per million as expressed in $CaCO_3$ and not like the Germans in degrees, which are parts per 100,000 as expressed in CaO. Using a 100 ml. sample, a N/10 potassium palmitate solution, and reading the burette to 0.1 ml. we could therefore determine the hardness to 5 p.p.m. If we use a N/25 potassium palmitate solution we could theoretically increase the sensitivity to 2 p.p.m.

On trial it was found that this increased sensitivity was not attained, as the weaker solution gave a very indefinite end-point. Yet further studies showed that the sharpness of the end-point of the titration with an alcohol-glycerine solution of potassium palmitate varies greatly with the glycerine content and that there is a clear maximum with a solution containing 42 per cent of glycerine by volume. Such a solution is therefore recommended. The detailed description of the method and of the preparation of the special reagent follows.

Reagents. N/50 hydrochloric, sulfuric or nitric acid.

N/50 sodium hydroxide, kept free of CO_2.

Methyl orange solution, 0.5 gm./liter of water.

Phenolphthalein solution, 5 gm. in 1 liter 50 per cent alcohol.

N/25 potassium palmitate solution. This solution can be made in two ways, depending on the chemicals available.

(a) With potassium palmitate. Dissolve 11.74 gm. of a very pure grade of potassium palmitate in 420 ml. glycerine and 400 ml. of 95 per cent alcohol over the steam bath or water bath. Frequent shaking is necessary. When dissolved, cool and fill up to 1 liter mark with 95 per cent alcohol.

(b) With palmitic acid. Dissolve 10.25 gm. of a very pure grade of palmitic acid in 420 ml. glycerine and 300 ml. of 95 per cent alcohol over steam bath or water bath with frequent shaking. When dissolved add 125 ml. of an alcoholic potassium hydroxide solution (15 gm. KOH in 1 l. of 95 per cent alcohol) and shake. Cool, add 2 ml. of phenolphthalein solution, and titrate in more of the KOH solution until the solution is slightly pink. Fill up to the one liter

mark with 95 per cent alcohol. Eventually add a further drop of the KOH solution to neutralize the acidity in the alcohol.

Standardization. The potassium palmitate solution should be standardized against an N/25 barium chloride solution. Dissolve 4.886 gm. $BaCl_2 \cdot 2H_2O$, in one liter of distilled water. Check the strength of this solution by analysis (gravimetric by precipitation of $BaSO_4$) as the water content of the barium salt is somewhat indefinite. (If 100 ml. sample was used for the precipitation of $BaSO_4$, then gm. $BaSO_4 \times 0.085684$ = Norm. of $BaCl_2$ solution.)

The $BaCl_2$ solution has to be diluted for the standardization. Each ml. of $BaCl_2$ solution requires 1 ml. of potassium palmitate solution of equal strength. It is best to dilute it to a hardness corresponding to the average hardness of the water to be tested in order to get about the same color standard in the test as in the standardization. For water of a hardness of about 200 ppm. $CaCO_3$ 5 ml. of the $BaCl_2$ solution should be used in 45 ml. distilled water. Standardize the pipette used for measuring the $BaCl_2$ solution. The procedure is then exactly as in the test for total hardness, except that the sulfuric acid cannot be used.

Calculation:

$$N_{K\ palm.} = N_{BaCl_2} \frac{ml._{BaCl_2}}{ml._{K\ palm.}}$$

One ml. of a N/25 potassium palmitate solution precipitates 2.0016 mg. $CaCO_3$, therefore, one ml. of the $N_{K\ palm.}$ solution precipitates

$$2.0016\ N_{\frac{K\ palm.}{0.04}}\ mg.\ of\ CaCO_3$$

or directly.

one ml. K palm. solution precipitates

$$50.04\ N_{BaCl_2} \frac{ml.\ BaCl_2}{ml.\ K\ palm.}\ mg.\ of\ CaCO_3$$

Test for Total Hardness. The test can be run on samples from 50 to 100 ml. We recommend that two samples of 50 ml. each shall be used.

To each 50 ml. sample of water, put in a 150, 200, or 250 ml. Erlenmeyer flask, add one drop of methyl orange.

Add the N/50 acid until the methyl orange turns red and then add 0.5 ml. acid in excess. Any of the three acids mentioned under reagents can be used. The test can also be made on the sample that

is used for the alkalinity determination. To get a good end-point in the alkalinity test, three drops of methyl orange are added. This gives too much coloring for the hardness test. It is in this case recommended that three drops of bromine water be added to the acid solution before boiling. This will destroy the color of the methyl orange. Any excess bromine will boil out with the carbon dioxide.

The acidified solution is then heated and boiled for one minute to expel the carbon dioxide. During the boiling the methyl orange may turn orange but on cooling it will turn red again. Cool the solution and add exactly 0.5 ml. of phenolphthalein solution. In field tests, where boiling is not feasible, CO_2 can be expelled by blowing air through the acidified sample for three minutes with an atomizer bulb.

So far all samples can be treated together. In the acid condition they are stable and will not absorb carbon dioxide. The following steps of the test should be finished as quickly as possible for each sample individually, one after the other.

Neutralize the excess acidity with N/50 NaOH to the pink of the phenolphthalein. The red of the methyl orange will first disappear and the solution turns pale orange, then pink. Clear the solution from this pink color with ½ to 1 drop of N/50 acid. The solution is then exactly neutral. The palmitate is titrated immediately into this exactly neutral solution to the pink coloring used in the standardization. The potassium palmitate causes a precipitate of calcium and magnesium palmitate and the solution turns turbid, the more the harder the water. The end-point is easily seen provided there is not too much alcohol in the mixture. To avoid this, CO_2 free distilled water should be added to the solution if more than 25 ml. of the potassium palmitate solution are required. For each 20 ml. of CO_2 free distilled water added, 12 ml. of potassium palmitate solution can be used.

Calculation: When two 50 ml. samples have been titrated, the difference in the number of ml. of potassium palmitate solution used should not be more than 0.1 ml. The two results can then be added and considered the result of a 100 ml. titration. This number times ten gives the ml. that would be needed for a one liter sample and this number times the mg. $CaCO_3$ precipitate as determined in the standardization gives the hardness expressed in ppm. of $CaCO_3$.

A few special remarks may be made here.

We have found no difference in the action of the potassium palmitate solution, whether palmitic acid or commercially available potassium palmitate was used in its preparation, yet there is some difference in the price of the two chemicals. One hundred grams of potassium palmitate made by Kahlbaum costs about $2.00 and the same amount of palmitic acid made by Eastman $5.00. There may be some difference in the purity of these chemicals; the tests for purity are somewhat difficult for the average water works laboratory. Sulfuric acid can be added to a weighed sample of potassium palmitate, the sample is then dried and ignited and the potassium sulfate formed weighed. This test requires that there is no free alkali hydroxide present in the soap. The test gave somewhat erratic results with duplicate samples. Better would be a determination of the melting point, but melting points are only published for palmitic acid. It varies in different data books from 62.6 to 64 and seems therefore not to be known very definitely.

The test does not give only the hardness due to calcium and magnesium, but also that due to iron and manganese. In fact potassium palmitate forms an insoluble precipitate with many metals, including aluminum, barium, silver, lead and copper. For this reason barium chloride, which forms a very stable solution, can be used for the standardization. Other solutions could be used. Zink and Holland (8) found little difference in the standardization using $CaCl_2$, $MgCl_2$, $BaCl_2$ $MgSO_4$, $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $Ca(OH)_2$, and $Ba(OH)_2$. We recommend the use of $BaCl_2$ on account of the stability of this solution and the purity with which this salt is available.

Very hard water did not give at first any end-point to the titration. As the action of phenolphthalein is influenced by the concentration of the alcohol a determination was made of the maximum alcohol content allowable to get a color change. The limit was found to be at 22.3 per cent alcohol by volume. Therefore if the water is so hard that it requires so much of the potassium palmitate solution that the mixture contains over 22.3 per cent alcohol, the end-point will not be visible by a color change. Such water has to be diluted to keep the alcohol concentration below this point. The dilution has to be made with neutral CO_2 free distilled water, as the introduction of any acidity would require more potassium palmitate and indicate additional hardness. Such dilution water is not always available and it is therefore easier to dilute a water, which is known to be hard, (one having over 800 ppm. hardness) at the start of the test and so expel its CO_2 with that of the sample to be tested.

From the above it can be seen that it is important that the neutralization of the sample be made carefully. An acid sample would indicate more hardness than is present, an alkaline sample less.

The removal of CO_2 must be complete. Satisfactory results can be obtained by boiling the solution for at least one minute or by blowing CO_2 free air through it for at least three minutes. The first procedure may be practiced in the laboratory, whereas the second method is handier in field tests.

During the titration with potassium palmitate insoluble calcium and magnesium palmitates are formed. These make the solution turbid. In our experience this seems to improve the visibility of the end-point. The first appearance of a slight pink color cannot be taken as the end-point. Such a slight tint may persist for some time during the titration, but the appearance of the red color is sudden and gives a sharp end-point.

Nitrites when present over 0.2 ppm. have the property of reducing the color of the methyl orange during boiling, but do not otherwise effect the test. Cl, SO_4, and NO_3 ions have no influence on the test.

The accuracy of the test can be determined from those samples on which the full analysis was run parallel to the potassium palmitate test. Averaging those of our tests coming under this classification we find that we record an average error of 7.0 p.p.m. or 2.71 percent. This is a good correlation between a rapid test and the full analytical result. It has however to be noted, that whereas the error expressed in parts per million is about the same for hard and soft waters, the error expressed in per cent is larger for soft waters than for hard ones. We found about even distribution of the cases where Blacher's method gives high results compared to the analysis and to those where the results with potassium palmitate are low.

It may be asked if other soaps could be used for a similar test. Ordinary soap solution, as prescribed in Standard Methods for the soap hardness test, is recommended by Grant (9). It gives good results with hardness caused by calcium, but indicates only about one-tenth of the magnesium hardness. Potassium stearate was also tried and gave throughout high results indicating 10 to 20 per cent more hardness than was actually present in the water. Sodium palmitate and sodium stearate are much less soluble in an alcoholic solution and this causes difficulty in their use. Neither pure normal propyl nor isopropyl alcohol dissolve potassium palmitate at room temperature in a N/25 concentration. In a 50 per cent water alcohol mixture of these alcohols, the potassium palmitate dissolves easily,

but the end-point of the titration is somewhat indefinite. Gardinol, a sodium alkyl sulfate did not give any indication of an end-point with phenolphthalein.

We believe therefore that N/25 potassium palmitate in a solution of ethyl alcohol with 42 per cent glycerol by volume is the best reagent that can be used for a general rapid hardness test. We have tried this reagent with good success on many types of waters sent to our laboratory for analysis, and we use it regularly for short boiler analysis. We can recommend it therefore to all water works. We hope that our experiences with this test will be confirmed in general practice.

REFERENCES

(1) Blacher, Grünberg & Kissa. Chem. Zeitg., **37**: 56 (1913).
(2) Winkler. Zeitschr. f. analyt. Chemie., **53**: 409 (1913).
(3) Pflanz. Mitteilg. der Königl. Landesanstalt für Wasserhygiene, No. 17, p. 141 (1913).
(4) Nöthlich. Institute für Meereskunde. University of Berlin. Heft. 31. May 1936.
(5) Ohmüller-Spitta. *Untersuchung und Beurteilung der Wassers und Abwassers.* Berlin (1931).
(6) Habrich. Kl. Mitteilg Landesanstalt Wasser u. s. w. Hygiene. Berlin, **2**: 39 (1926).
(7) Werescagin. Archiv. für Hydrobiologie, **23**: 1–64 (1932).
(8) Zink und Holland. Zeitschr. f. angew. Chemie., **27**: 437 (1914).
(9) Grant, J. Water & Water Eng., **36**: 470 (1934).

DISCUSSION

(*Discussion by L. A. Nalefski*):* The need of a new rapid and more efficient method for total hardness determinations has long been felt. The old soap solution has been a standard for rapid determinations for many years in spite of the fact that its accuracy and results were often challenged. Errors of ten per cent or higher are not uncommon with this old method, and very often it has been found very difficult and even impossible to duplicate the results. The potassium palmitate method originally reported by Blacher in 1913 had possibilities which certainly demanded our consideration. The following equation illustrates the hydrolysis products at the end point: KPal + HOH = KOH + HPal. Kolthoff included this procedure in his book of technical analysis. The wide spread use of this procedure was prevented by the fact that it could not in its original form be adapted to all waters. The investigations by Dr. Suter has cleared

* Chemist, Decatur Water Department, Decatur, Illinois.

up such factors as alcohol-glycerin ratios, strength of solution, and the kind of alcohol best adapted to this method. Now it is readily adapted to all waters as the results of this research illustrates.

The potassium palmitate method as presented gives no method of approximating the amount of magnesium present, but several investigators have described methods in which the calcium salts could be removed and the magnesium determined as the residual hardness. This method, which calls for an additional operation in contrast with the ghost point of the old soap method, will give results comparable to those obtained by gravimetric methods. The potassium palmitate method is now being applied for sulfate determinations in boiler feed water control as well as residual hardness determinations in boiler water treatment.

Some opposition to the present method is from the standpoint of determining just where the end point occurs. Dr. Suter mentions that a slight pink color appears before the actual end point is reached, a decided red color appearing at this time. The appearance of this first pink color gave rise to the possibility of a fading end point. The existence of a so-called fading end point is justified at any time before the actual end point is reached. In our laboratories we have noted that the reaction appears to slow up as the stoichometric point is approached, resulting in the pink coloration disappearing more slowly. By watching this rather closely we have developed a sensitivity of two to three parts per million. The end point with distilled water using a N/25 solution was reached with 0.05 ml of the solution, which is equivalent to 2 ppm of hardness as CaO_3.

The method of standardization is considerably improved with this method. Dr. Suter recommends the use of barium chloride. This salt has two molecules of water of hydration and must be further analyzed to determine the actual barium content. We have found that the use of $CaCl_2$ solution as described in Standard Methods for soap solution standardization works equally well, and thus eliminates the additional analysis involved with barium chloride. Also we find that the use of a saturated solution of bromine water to destroy the methyl orange color is very helpful in obtaining a sharp end point. If bromine water is not available the alkalinity may be obtained by the usual procedure and a new sample used for the hardness determination. To this second sample is added the amount of acid necessary to neutralize the alkalinity plus 0.5 ml excess, and then applying the usual procedure.

EXPERIENCES IN FILTRATION*

By John R. Baylis

(*Physical Chemist, Experimental Filtration Plant, Chicago, Ill.*)

The purpose of this paper is to review briefly some of the past experiences in rapid filtration and to present more fully a few facts brought out in recent studies relating to the filtration of water. The limitations of the filter bed are becoming understood more thoroughly, and progress is being made in maintaining the filters in better condition than heretofore. As a result, more efficient operation of filtration plants is assured for the future. The filter operator is no longer merely a person capable of opening and closing valves in accordance with a set of instructions, who possesses little knowledge of what is taking place in the purification of the water. He is rapidly becoming a well trained person who understands the chemical reactions involved in the treatment of the water, and the hydraulic and other physical forces involved in the passage of the water through the plant. This type of person takes pride in keeping the filters operating at their maximum efficiency.

Special short courses in water treatment and filtration are now being offered at so many places throughout the United States that these schools are within the reach of nearly every one engaged in water purification. It is gratifying to see so many attending such courses. Certainly these operators return to their work better qualified to perform their duties.

Fuller (1) stated that little progress was made in the filtration of water in America before publication of the Kirkwood Report in 1869. For a quarter of a century this report was the leading guide on filtration practice through the description it gave of filtration plants in Europe. Fuller divided the period following the Kirkwood report into four periods. (1) The early beginning, from 1869 to 1886; (2) a period of research and development, from 1887 to 1902; (3) a period of rapid practical accomplishment, from 1903 to 1918; and (4) the period of refinement, from 1919 to 1933. The article was

* Presented before the Florida Section, March, 1937.

written in 1933, and did not intend to convey the impression that the fourth period ended in 1933. The word "refinement" is somewhat indefinite and may include many things. A better definition of the period from 1919 to date is a period of intense research and refinement in operation.

The writer became interested in filtration in 1912, which was towards the latter part of the third period given by Fuller. It was a period of rapid construction of filtration plants, and was attracting many engineers and chemists to this line of work. There has not been radical change in the design of filters since then, but many refinements, particularly in the treatment of the water, have been put into practice.

Mechanical rakes were almost abandoned by 1912, or at least were not being included in many new designs, probably largely because of the desire to construct rectangular instead of circular filters. Air to aid the washing of filters was being installed in many plants, and the high rate of washing filters also was being used to a considerable extent. Perhaps it may be of interest to relate something about the operation of filters at this time.

Filter Operation in 1915. This date is selected because it is the year in which the writer began his experience in the operation of filters. Hydrogen ions were not known to filter plant operators, and almost no progress in the chemistry of water treatment had been made since the work of Fuller and his associates at Louisville (2). Two coagulating substances were being used—aluminum sulfate and ferrous sulfate. Ferrous sulfate was being used in only a few plants, though some of these were the larger ones. The greatest worry of the plant operator was to produce and maintain good coagulation. This was particularly true for the low alkalinity waters. The treatment might be producing good coagulation one minute and then without apparent reason there would be poor coagulation. Lack of mixing facilities contributed to the difficulty. Frequently the operator did not know which way to change the treatment when good results were not being produced, and he did not know how to make tests on the water which would tell him what to do. Stirring machines were not in use in any of the laboratories, and the opinion amongst all operators was that one could not tell from laboratory tests what to expect in the plant.

Such conditions did not insure a properly treated water reaching the filters all the time, and in many plants the influent water to the

filters frequently contained much more material than filters, even in the best of condition, could handle. Combined with the water not being coagulated properly at times, the filters in some instances were in very bad condition and would not remove all of the coagulated material when the water was properly coagulated. Public health authorities exercised little control over the bacterial quality of the water. Chlorine was being used in some of the filtration plants, though many were without facilities for adding chlorine. In many plants where facilities existed, the chlorine either was not used regularly, or it was not used in amounts adequate to give good sterilization of the water.

Turbidity tests were made on the raw water, and if the filtered water was not distinctly cloudy the turbidity was recorded zero. Bacteriological tests were made in the larger and medium sized plants and probably a few of the smaller plants. Most of the plants could show considerable bacterial reduction. In some of the smaller plants, operators with no chemical training made the turbidity and alkalinity tests. The larger plants employing several laboratory workers made a number of tests, and fairly good records of the plant performance were kept. Such tests as alkalinity, turbidity, free carbon dioxide, iron, the number of bacteria, and the number of bacillus coli were made regularly. Sometimes other tests such as odor, dissolved oxygen, oxygen consumed, ammonia, nitrates, nitrites, soap hardness, and certain other tests were made at least at occasional intervals. The second edition of Standard Methods of Water Analysis, published in 1912, did not contain a method of determining residual chlorine in water.

Except for the larger plants, one man usually was responsible for the entire operation of the plant. He applied the chemicals to the water; made the various tests, if any were made on the water; and washed and kept the filters in operating condition. This, of course, is common practice in small plants today, though present operators usually are better trained for their work. The water now is sampled and tested by public health officials at intervals frequent enough to obtain a very good idea as to its quality, and if the water is not up to standard, the operator is called upon to account for the reason. In 1915 the public usually was forced to take such water as the person operating the filtration plant chose to produce, and occasionally the standard of quality set by this person was not very high. Some of the plants were interested in saving every dollar possible, and sometimes did not add enough chemicals to coagulate the water properly.

The filter beds varied from beds in excellent condition to mounds of sand and mud comprising most of the bed. Occasionally when they became badly fouled all of the material was removed and new material added, or the old material rescreened and replaced. It was nothing uncommon to have to rebuild the filter beds every year or two. Every one engaged in filtration work at that time seemed to be of the opinion if the proper type of underdrain could be perfected all filter bed troubles would be eliminated when the water was properly treated. This inspired those of an inventive mind, and resulted in many suggestions for filter bottoms. Some of the newer ideas were tried but with little success.

Fouled filter beds were frequently causing bacterial growths in the warmer months. Various opinions as to the cause of the after-growths were offered, with the prevailing opinion being that the growths originated in stagnant places formed at the bottom of the gravel below the strainers. Frequently the underdrain pipes were covered with cement mortar. Between the strainers the cement occasionally was pyramided so that there could be no stagnant spots of water. Why the gelatinous coating on the sand grains and the fine gravel, and the accumulation of organic matter in mud balls was ignored as a source of bacterial growths is difficult to understand. Especially when this offered a surface area probably a thousand times greater than the area of the surface of gravel not directly in the line of flow of the water through the filter. The peculiar part of much of the effort heretofore made to keep filter beds in good condition is that it has been directed along lines which now seem least likely to produce effective results.

Improvements in Water Purification. When public health officials began to demand a better bacterial quality of water, the use of chlorine became extensive. The ortho-tolodin test for residual chlorine, first suggested by Phelps, was developed into a practical means of testing the residual chlorine by Ellms and Hauser (3) in 1913. Wolman and Enslow (4) in 1919 suggested the addition of chlorine to water until there was residual chlorine left in the water after treatment. This was the practical solution of bacterial difficulties in the purification of contaminated waters.

The hydrogen ion concentration of water began to attract attention in 1921 and the pH test was soon found to be very helpful in telling if the water was at an equilibrium for proper chemical reactions. Certain things relating to formation of the coagulation,

which had perplexed the filtration chemists for years, were more clearly understood when the hydrogen ion concentration of the water was known. Soon the test became indispensable for proper treatment of the water. Treatment of water to reduce its corrosiveness by use of lime was started in Baltimore in 1919, and now nearly every highly corrosive, and many of the moderately corrosive waters are being treated. This, of course, applies largely to waters where there are treatment and filtration plants.

Use of a submarine light in the clear water reservoir (see Figure 1), one of the most helpful devices in filter plant operation, came into use about 1918. A floc detector for detecting the passage of coagulated matter through filter beds was perfected in 1921, and a turbidimeter for measuring low turbidities was devised in 1923. Very few floc detectors have been installed, but low turbidity measurements have come into extensive use.

No definite date marks the beginning of the use of mixing basins, though it was about 1920 before nearly all of the designing engineers had become convinced that a mixing basin was a very desirable feature of the filtration plant. The writer is of the opinion that the introduction of laboratory stirring machines in some of the laboratories for studying coagulation has been responsible for convincing many of the value of good mixing. However, there were many plants constructed with mixing basins long before laboratory devices were introduced.

Little Attention Given Filter Beds. Soon after starting operation of a filtration plant at Jackson, Mississippi, in 1915, the writer became convinced that maintaining the filter beds in good condition was a real problem confronting those engaged in water purification, for it was necessary to reconstruct the filter beds in this plant after about 18 months of operation. They were reconstructed only after they were in very bad condition and should have received attention earlier. The writer's next experience was as an employee of the Montebello Filters, Baltimore, beginning in 1917. This was one of the larger plants, and had been in operation about 2 years. The design embodied the latest features in water purification at the time of its construction, yet the filter beds in this plant developed the usual clogging troubles. There may have been reason to believe the design of the underdrainage system at Jackson was responsible for some of the filter bed trouble at that plant, but there could be no doubt about the underdrains at Baltimore producing an even distribution of the wash water.

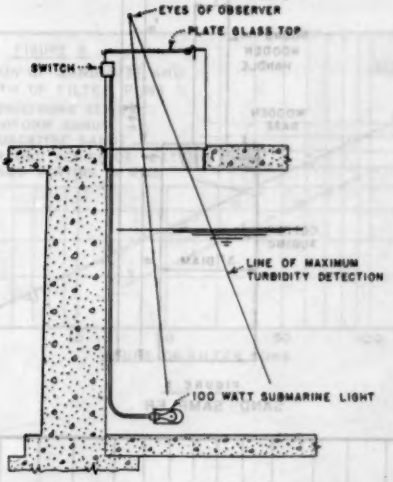


FIGURE 1
SUBMARINE LIGHT FOR TURBIDITY DETECTION

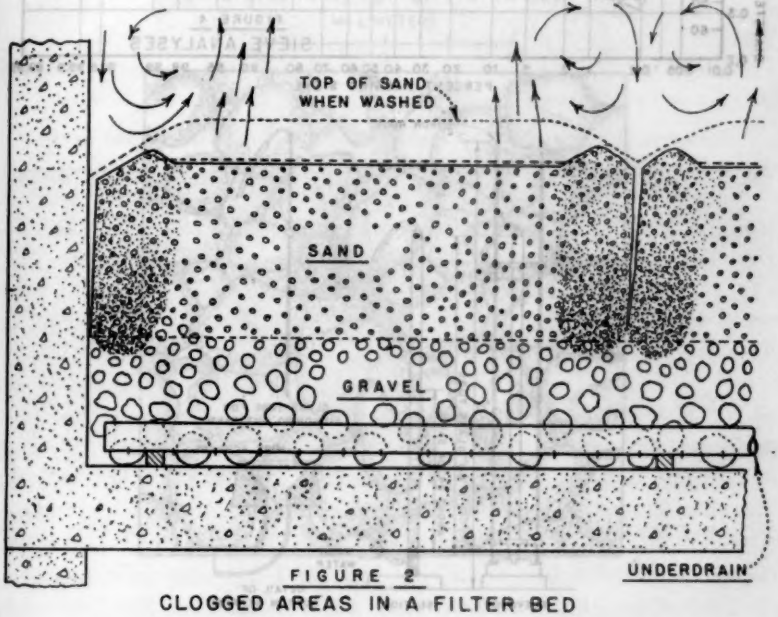


FIGURE 2
CLOGGED AREAS IN A FILTER BED

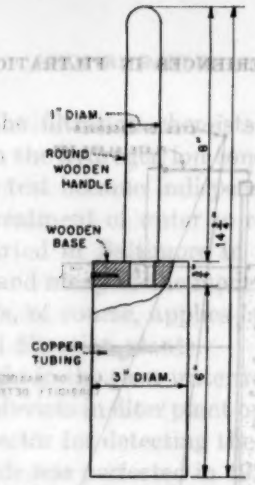


FIGURE 3
SAND SAMPLER

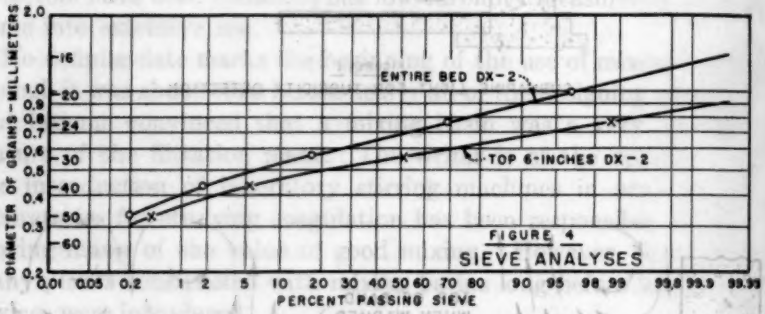


FIGURE 4
SIEVE ANALYSES

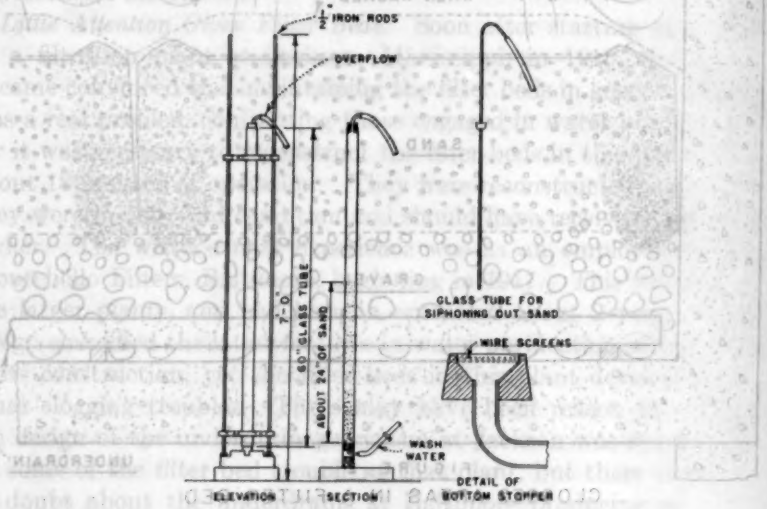


FIGURE 5
FILTER FOR TESTING POROSITY OF FILTERING MATERIAL

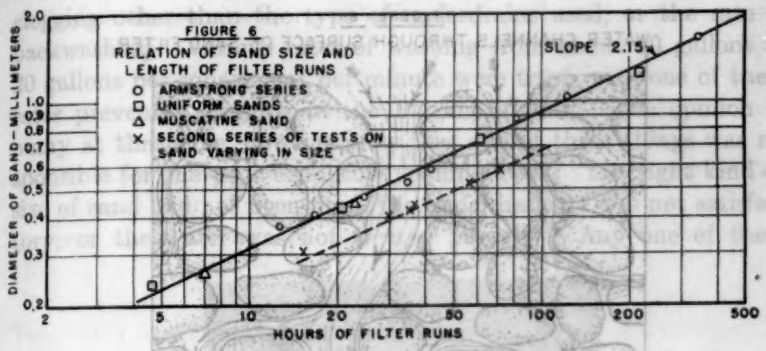


FIGURE 6
RELATION OF SAND SIZE AND LENGTH OF FILTER RUNS
O ARMSTRONG SERIES
□ UNIFORM SANDS
△ MUSCATINE SAND
× SECOND SERIES OF TESTS ON SAND VARYING IN SIZE
SLOPE 2.15
DIAMETER OF SAND - MILLIMETERS
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
2
5
10
20
50
100
200
500
HOURS OF FILTER RUNS

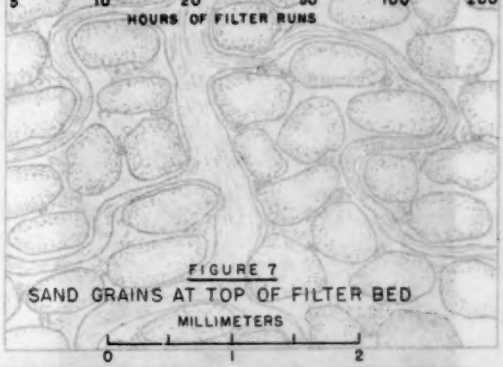
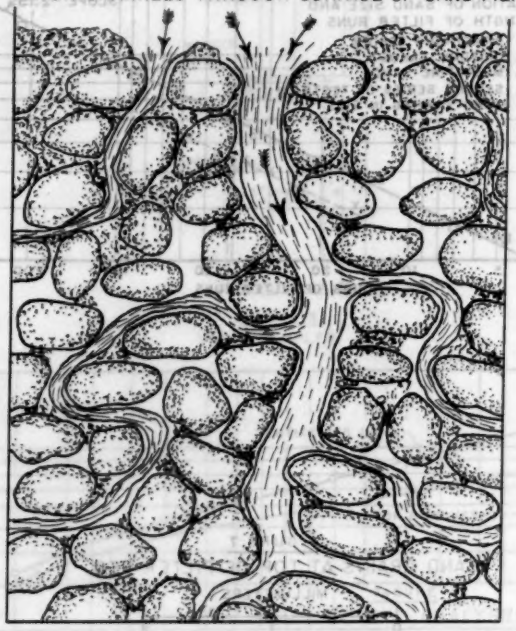


FIGURE 7
SAND GRAINS AT TOP OF FILTER BED
MILLIMETERS
0
1
2

FIGURE 8

WATER CHANNELS THROUGH SURFACE OF SAND FILTER



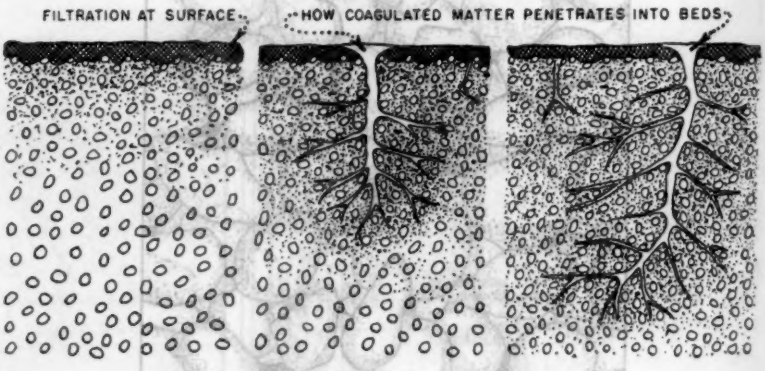


FIGURE 9

SKETCHES SHOWING WHAT TAKES PLACE IN A FILTER BED

The opinion then was formed that there was cause for filter bed clogging other than the type of underdrains used, or the rate of backwashing. Various rates of washing from about 10 gallons to 20 gallons per square foot per minute were tried, yet none of these rates prevented clogging in the Baltimore plant. The opinion of many at that time, however, was that one of three things was responsible for the poor conditions of filter beds. The right kind or size of sand had not been used, the underdrainage was not satisfactory, or the water was not treated properly. Any one of these

FIG. 10. HOLES THROUGH SURFACE OF A FILTER BED (NATURAL SIZE)

things might have, of course, contributed to the situation, but as there was good mixing, and the settling also was good, this could not have been the cause at Baltimore.

The underdrainage system of the Baltimore filters could be eliminated as a possible cause, for there was no evidence of uneven distribution of the wash water. The quality or size of sand in some of the beds may have been open to question, but reconstructed beds with sand of larger and more uniform size did not prevent the trouble to any material extent. The only conclusion which could be formed was that the best constructed washing systems were not adequate

in some plants to keep filter beds as clean as they should be kept. A study of the filter beds in the Baltimore plant was published in 1924 (5). The opinion then was recorded that the most practical means of keeping filter beds in good condition was by use of a much more violent force than had been used previously, such as a surface washing system to aid the backwash.

This early work on the maintenance of filter beds failed to attract attention largely because nearly every one engaged in filtration work still believed that there was some kind of underdrainage system, which, if perfected, would keep the beds in perfect condition providing the right size sand was used and the water was properly conditioned before it reached the filters. Why many retained this belief so firmly in the face of trials of almost every conceivable kind of filter bottom, every size of sand fine enough to remove the coagulated matter, various rates of backwashing, and good conditioning of the water before filtration, is difficult to understand. Even at this time many are still of the opinion that some slight modification of existing practice is going to enable the operators to keep the filters in good condition, and that use of a surface washing system is expensive and not necessary.

FILTER BED TROUBLES

A somewhat lengthy discussion of filter bed troubles and their elimination was published recently (6). The data presented showed that much of the filter bed trouble originated from an accumulation of compacted coagulated material not removed by the washing system, and to coatings on the sand grains. Shrinkage or settlement of the beds while in service usually is caused by a soft coating around the sand grains which is not removed by backwashing the filters. This shrinkage allows cracks to open along the sidewalls and occasionally in other parts of the bed. This aids the formation of clogged places and allows some of the water to bypass the finer sand at the surface of the bed. Clogged areas frequently form along the sidewalls of filters, and when they become very large as shown in Figure 2, cracks may open nearly to the gravel. Also clogged areas sometime form in other parts of the bed when the tendency to form mud balls is great. Such a clogged place also is shown in Figure 2. The higher the rate of backwashing the deeper the mud balls sink into the sand during washing, but they do not have as great tendency to clump together at the high rate as they do at lower rates.

MEASURING THE VOLUME OF MUD BALLS

Measurement of the volume of mud balls in filters gives a good indication of the effectiveness of the washing system in keeping the beds in proper condition, and while the method has been described in other publications its importance justifies giving the procedure in detail. As more of the mud balls are found in the upper part of the sand beds than any other part, collecting samples of the sand from the top 6 inches of the bed is believed to be satisfactory. A sampling device similar to the one shown in Figure 3 is satisfactory. It is made from a thin copper tube about 3 inches inside diameter and 6 inches long on the inside. The volume of the tube has to be determined before using.

Collecting Samples. The filter is washed, the water drawn down to 12 or more inches below the surface of the sand, and then the sampler is pushed down 6 inches into the sand. The sampler is tilted to where it is in a nearly horizontal position and is then lifted full of sand. The tilting and raising at the same time breaks up the sand around the tube but the sand inside is not disturbed. The sand being moist, there is no difficulty in keeping the tube full without placing the hand over the end of the tube, if the diameter is not more than about 3.5 inches. Collect the sample from 4 or more places in the bed so that the combined sample will be representative of the entire top six inches of the bed.

Screening Mud Balls from the Sand. The sand it washed from the mud balls by means of a 10-mesh sieve. Portions of the sample collected are placed in the sieve, and the sieve lowered under water to near the point of submergence. Gently raise and lower the sieve about one-half inch at a time until all of the sand is washed through.

Do not place too much sand on the sieve at one time, as this may break up some of the mud balls and cause them to be washed through the sieve. If only a few mud balls remain on the sieve after a portion of the sand is washed through, they need not be removed before adding additional sand to the sieve. Move the mud balls to one side of the sieve by tipping the sieve a little and when partially submerged raise and lower the sieve as well as move it sideways a little. The downward and sideways motion should be sufficient to pile up the mud balls on one side of the sieve. With a little practice this may be done without breaking up the mud balls. Pass all of the sand through the sieve—transfering the mud balls from the sieve when there is considerable accumulation.

Measuring Volume of Mud Balls. The volume of mud balls is measured by displacement of water in a cylinder graduate. Fill the graduate to the one-half mark, or some other mark, with water. After the water has drained from the mud balls in the sieve, transfer them to the graduate, and read the increase in volume. Knowing the volume of the sample of sand collected, and the volume of mud balls, the percentage of the volume of mud balls in the sand may be computed. Assume that the total quantity of sand and mud balls collected has a volume equal to that of a 6-inch cube (3,540 cc.), and that the volume of mud balls determined by measurement is 116 cc., the volume of mud balls is 3.28 percent of that of the sample. This is not the percentage volume of the total bed but the top 6 inches of the bed. The size cylinder graduate to use will depend upon the volume of mud balls measured. If the volume is less than 10 cc., a 25-cc. or 50-cc. graduate is satisfactory, and if the volume is about 100 cc. a 500-cc. graduate probably is the best size to use.

TABLE 1

Classification of filter beds

PERCENT VOLUME OF MUD BALLS	CONDITION OF FILTERING MATERIAL
0.0 to 0.1	Excellent
0.1 to 0.2	Very Good
0.2 to 0.5	Good
0.5 to 1.0	Fair
1.0 to 2.5	Fairly Bad
2.5 to 5.0	Bad
Over 5.0	Very Bad

Classification of Filter Beds. The proposed classification of the filter beds based upon the volume of mud balls in the top six inches of sand is given in Table 1.

Efforts should be made to keep the mud ball volume less than 0.1 percent of the volume of sand or other filtering material. This applies to the top six inches of the filter bed, or to any other portion of the bed, should there be some other portion which exceeds this limit. Where the percentage volume of mud balls exceeds 0.2 percent, extra facilities for washing the filters should be provided, such as the surface wash. For light materials, such as anthracite coal, the mud balls may not accumulate at the top of the bed as is the case for sand beds. In such cases the portion of the bed where the mud balls are most likely to accumulate should be measured.

EFFECTIVE SIZE OF FILTERING MATERIALS

Hazen (7) was the first to offer a method of grading sand to be used in filter beds according to size and uniformity. The method was developed primarily for slow sand filters, though when rapid sand filters began to be used, it was found that the method worked fairly well for this type of filter. Very few attempts have been made to change the Hazen method, though many are of the opinion that it does not give the true effective size of filtering materials in beds backwashed as is common practice for rapid sand filters.

Such other methods as have been offered heretofore for classifying filtering materials have not shown any superiority over the Hazen method and consequently never came into general use. Burgess (8) recommended changing the standard of measurement from the size of sand grain to the size of opening of the sieves, and also suggested doing away with the term "effective size." Tyler (9) suggested the use of a surface modulus for filter sand. Engineering News-Record (10), in 1931, obtained the views of a few of the filtration engineers on the Hazen method of classifying sands. Most of those commenting on the method thought it was fairly satisfactory. At least they did not favor any of the suggested modifications which had been made up to that time.

Experiments at the Chicago Experimental Filtration Plant on various sizes and gradings of filtering materials indicate that the Hazen method does not classify the materials properly according to size except for materials reasonably uniform in size. The data indicated that using the average of a combination of sizes gave a better classification according to size. The writer is of the opinion that the improved method has considerable merit and while some modification may need to be made when more data is available, its use as now recommended gives results closer to the true effective size than any other method. The procedure for determining effective size by the new method is given in detail.

THE IMPROVED METHOD

Equipment. Standard sieves, preferably 8 inches in diameter. One each of sieves having the following meshes per inch will be suitable: 4, 6, 8, 10, 16, 20, 24, 30, 35, 40, 50, 60, 80, and 100. Two tops and two receivers may facilitate the work where a number of samples are to be tests, though one top and one receiver are all that is necessary.

Ro-tap machine with capacity for at least 6 sieves.

Device for splitting samples, such as Jones riffle sampler.

Balance with weights, capacity at least 300 grams, and accurate to 0.1 gram.

Several pans and beakers.

Sieve brush.

Logarithmic probability, or logarithmic cross section paper.

Procedure for Sieving. Dry the sample of material at 100 to 110 degrees C.

Divide into halves with a Jones riffle sampler, or by spreading on a paper. Keep dividing until a portion is obtained that weighs between 100 and 200 grams, and preferably from 100 to 150 grams.

Weigh all of one of the divided portions. If approximately 1000 grams are in the sample, the first division will give portions weighing approximately 500 grams each. The division of one of these portions will give portions weighing about 250 grams, and another division of one of these portions will give portions of approximately 125 grams. Weigh accurately one of these portions.

Use standard sieves which have been calibrated accurately. Not more than about 100 sievings should be made between calibrations. Nest the sieves in the order of size of opening, with the sieve of largest openings on top. Use enough sieves so that not more than 1 percent by weight of the material will be retained on the sieve of largest openings and less than 1 percent of the material will pass the sieve of smallest openings. At least 6 sieves should be used, and occasionally it is desirable to use more.

Shake in a ro-tap machine or other suitable mechanical shaker for 15 minutes. Hand shaking may be used when a mechanical shaker is not available, but the shaking should be done by someone who knows the approximate amount of hand shaking required to equal that of 15 minutes of a mechanical shaker. Not more than three sieves should be used at a time when the shaking is done by hand.

Weigh the amount of material retained on each sieve, and total to see if the sum is the same as the original weight.

Determination of Size of Material. Calculate the percentage of material remaining on each sieve, the total of which should be 100. Then compute the percentage of material which will pass each sieve. Table 2 gives method of recording the sieve results.

Plot on logarithmic probability, or logarithmic paper the percent

weight passing the various sieves. Use the logarithmic scale for the diameter of the largest grains which will pass sieves, that is, the calibrated sieve size instead of the opening stamped on the sieve. If a calibration has not been made, 1.1 times the opening stamped on the sieve should be close to the largest size grains which will pass through the sieve before the sieve becomes worn through usage.

TABLE 2

Sieve analysis of Muscatine sand placed in filter DX-2

SIEVE	GRAMS RETAINED ON SIEVE	TOTAL GRAMS PASSING SIEVE	PERCENT PASSING SIEVE
10	0.0	100.6	100.0
16	0.0	100.6	100.0
20	3.4	97.2	96.5
24	27.6	69.6	69.3
30	52.2	17.4	17.3
40	15.6	1.8	1.8
50	1.6	0.2	0.2
Less than 50	0.2		

1 Percent Size	0.400 mm. dia.
2 " "	0.435 " "
4 " "	0.457 " "
8 " "	0.500 " "
16 " "	0.550 " "
32 " "	0.615 " "
64 " "	0.730 " "
Average of 1 to 16 percent diameters	0.470 mm.
" " 1 to 32 " "	0.495 "
Percent of material of diameter less than 1.5 times the 1 percent size	28
Diameter of effective size of the sand	0.489 "
Percent of material less than 1.0 mm. dia	97.0

The probability scale is used for the percent passing the sieves. Draw a line through the points, curving the line rather than making abrupt breaks at the points. One of the lines in Figure 4 show plotting of the analysis given in Table 2.

From the plotting, determine the 1, 2, 4, 8, 16, 32, and 64 percent sizes. A certain percent size means that this percent of the material by weight is of the size and smaller. In addition to determining these sizes, determine the percent of material which is smaller than

1.5 times the 1 per cent size. This is called the *effective size* range. Also determine the percent of material 1 mm. dia. and smaller.

Average the 1, 2, 4, 8, 16, and 32 percent sizes, except that no size beyond the effective size range is considered if it is less than 32 per cent of the material. As the effective size range will likely fall between some two of the figures given in the geometric ratio instead of being exactly 8, 16, or 32 per cent, some means of taking this into consideration should be used. A procedure accurate enough for practical purposes is to average the figures below the effective size range for one value, and average these figures together with the next figure above the effective size range, and proportion the difference in proportion to the position of the effective size range figure between the two figures in the geometric scale. The sieving in Table 2 may be used for illustration. The effective size range determined from plotting the results of sieving is 28. The average of the 1, 2, 4, 8, and 16 percent sizes is .470 mm. dia. The average of the 1, 2, 4, 8, and 32 percent sizes is .495 mm. dia. The difference is 0.025 mm. The difference between 16 and 32 is 16. 28 is 12 figures from 16 and 4 from 32. 12/16 of 0.025 is 0.019. Adding this to 0.470, the effective size of the material is 0.489 mm. dia.

For material about as uniform as is obtained in the average filter sand, the effective size range will be between 16 and 40. Should it be a figure over 32 percent, no figure higher than 32 is used in determining the effective size, so the size in such cases will be the average of the 1, 2, 4, 8, 16 and 32 percent sizes. When the material is irregular in size, the effective size range may be as low as 4 or 5 percent. Should it be 4 percent, only the 1, 2, and 4 per cent sizes are averaged to obtain the effective size.

The new method of determining the effective size of filtering material usually gives figures slightly lower than the Hazen method, but the results are so close to the Hazen size for good filtering materials it may be said to be almost the same. Table 3 gives comparison of the Hazen method with the new method on a number of filtering materials. The closeness of the size determined by the two methods for the regular filter sands indicates that either method is satisfactory for such materials. The difference in the results on some of the materials irregular in size is striking, and shows that one of the methods will not properly classify the material according to size. The superiority of the proposed method in giving a relation between sand size and length of filter run is shown by figure 6. If

TABLE 3

Comparison of sands by Hazen and by the improved methods

SAMPLE	HAZEN METHOD			IMPROVED METHOD	
	Effective size (10 per cent)	60 per cent size	Uniformity coefficient	Effective size	Effective size range
	mm.	mm.		mm.	
1 Muscatine sand	0.500	0.75	1.50	0.469	24
2 " "	0.530	0.74	1.40	0.488	24
3 " "	0.503	0.700	1.39	0.459	20
4 " "	0.510	0.71	1.39	0.473	22
5 " "	0.515	0.74	1.43	0.472	20
6 " "	0.495	0.675	1.38	0.477	33
7 " "	0.510	0.700	1.37	0.486	30
11 Lake Michigan sand	0.171	0.243	1.42	0.162	28
M-1 Armstrong*	0.520	0.730	1.40	0.515	38
N-1 "	0.356	0.582	1.64	0.307	13
O-1 "	0.583	0.838	1.44	0.568	40
P-1 "	0.415	0.590	1.42	0.400	45
Q-1 "	0.438	0.625	1.43	0.422	34
R-1 "	0.456	0.860	1.45	0.430	28
M-2 Uniform†	1.94	2.42	1.25	1.78	23
N-2 "	1.33	1.67	1.25	1.27	95
Y-1 "	0.87	1.05	1.21	0.854	85
P-2 "	0.77	0.88	1.14	0.738	89
Q-2 "	0.555	0.65	1.17	0.543	95
R-2 "	0.444	0.501	1.13	0.434	99
S-2 "	0.290	0.357	1.23	0.279	38
T-2 "	0.243	0.280	1.15	0.235	94
AX-1 Muscatine sand	0.555	0.650	1.17	0.526	
BX-1 " "	0.555	0.650	1.17	0.573	
CX-1 " "	0.555	0.650	1.17	0.623	
AX-2 " "	0.505	0.706	1.40	0.470	24
BX-2 " "	0.505	0.706	1.40	0.470	24
CX-2 " "	0.505	0.706	1.40	0.470	24
DX-2 " "	0.505	0.706	1.40	0.470	24
J-3 Anthracite coal	0.588	1.300	2.21	0.632	
J-4 Muscatine sand	0.490	0.686	1.40	0.476	33
DX-1 " "	0.526	0.744	1.41	0.444	9
EX-1 " "	0.336	0.575	1.71	0.257	7.5
FX-2 Armstrong*	0.383	0.755	1.93	0.370	27
GX-2 "	0.418	0.79	1.87	0.403	29

* Sand sieved and sent to various filtration plants for experimental purposes by James W. Armstrong, Baltimore.

† Sieved at the Chicago Experimental Filtration Plant.

TABLE 3—*Concluded*

SAMPLE	HAZEN METHOD			IMPROVED METHOD	
	Effective size (10 per-cent)	60 per-cent size	Uniformity coefficient	Effective size	Effective size range
	mm.	mm.		mm.	
HX-2 Armstrong*	0.490	0.77	1.57	0.477	34
D-5 "	0.539	0.834	1.55	0.527	37
Z-3 "	0.644	0.931	1.45	0.582	18
JX-2 "	0.870	1.80	2.07	0.877	32
LX-1 "	1.15	2.45	2.13	1.031	16
MX-1 "	1.93	3.17	1.64	1.62	11.5
T-4 Crushed Quartz	0.52	0.74	1.42	0.453	12
FX-3 Muscatine sand (16")	0.56	1.22	2.18	0.482	8.5
EX-2 Crushed Glass (16")	0.66	1.49	2.26	0.515	5.6
DX-2 Muscatine sand	0.513	0.716	1.39	0.489	28
JX-3 Ottawa sand	0.520	0.66	1.27	0.503	54
EX-3 Copley, crushed quartz	0.499	0.705	1.41	0.475	28
D-6 Ottawa and Berkshire sand	0.440	0.560	1.28	0.272	8
FX-4 Minchar	0.517	0.685	1.32	0.509	59
HX-3 Anthracite coal	0.495	0.700	1.42	0.457	22
Z-4 Crushed glass	0.51	0.750	1.47	0.432	12
GX-3 Cocoanut char	0.535	0.680	1.27	0.515	52
AX-2a	0.510	0.700	1.37	0.470	24
9 Ottawa sand	0.324	0.465	1.43	0.266	14
10 Red Wing sand	0.490	0.698	1.42	0.395	8
11 Phalanx sand	0.621	0.897	1.44	0.600	42
12 Cape Cod sand	0.491	0.663	1.35	0.470	35
13 Ottawa sand	0.370	0.735	1.99	0.300	11
14 Cape May sand	0.430	0.780	1.81	0.363	9
15 Phalanx sand	0.416	0.600	1.44	0.393	28
16 Muscatine sand	0.595	0.870	1.46	0.523	16
17 Ottawa sand	0.550	0.830	1.51	0.529	22
18 Muscatine sand	0.600	0.987	1.65	0.402	4.5
19 Ottawa sand	0.540	0.808	1.50	0.511	25
20 Copley, crushed quartz	0.540	0.765	1.42	0.510	26
21 Ottawa sand	0.341	0.544	1.60	0.284	10

the proposed method shows great superiority in irregular materials, then it likely has some superiority in determining the size of materials extensively used in filter beds.

Effect of Depth of Bed on Effective Size at the Sand Surface. Since there is always a partial stratification of the filtering materials resulting from washing the filters with an upward flow of water suffi-

cient partially to suspend the material, the depth of the bed influences the effective size. The method of determining sand sizes used heretofore has not taken this into consideration. Regardless of the method which may be used in the future, the effect of the depth of the bed should be considered. As the sand in many filter beds is

TABLE 4

Summary of lengths of filter runs for various depths of beds

Depth of bed in inches	36	24	12	6
Effective size of sand in millimeters	0.526	0.543	0.573	0.623
MONTH	HOURS FILTER RUNS TO 8 FEET LOSS OF HEAD			
June 1931	45.9	54.0	54.5	47.9
July	58.3	60.0	56.4	68.0
August	63.7	52.5	62.6	81.8
September	55.0	53.0	47.2	62.3
October	92.6	115.6	108.0	127.0
November	100.8	100.8	115.0	129.0
December	66.3	70.9	90.0	98.1
January 1932	34.5	36.0	37.2	47.0
February	30.6	49.0	46.7	66.7
March	33.9	47.2	48.1	68.7
April	20.6	30.1	40.9	48.3
May	7.1	9.3	8.8	12.7
June	13.6	18.1	16.8	20.7
July	40.6	41.3	41.6	47.7
August	29.9	34.1	33.0	41.9
September	47.1	30.4	46.7	60.9
October	37.5	24.2	39.5	53.0
November	38.9	20.3	41.1	56.5
February 1933	20.5	11.5	24.5	43.3
March	32.9	18.3	36.9	53.7
Average	43.5	43.8	49.8	61.8
Computed from K = 165 in equation $H = KD^{2.15}$ (see page 1039)	41.4	44.4	49.8	59.6

about 24 inches in depth, this will be regarded the standard depth. Assume that the bed is only 18 inches in depth. There will be a lesser thickness of small materials at the top than for a bed 24 inches in depth, therefore the real effective size will be larger. A method for taking the effect of depth of bed into consideration will be given.

Sieve a sample of the sand and determine the percentage of the material which passes the various sieves. Multiply these percentages by the actual depth of the bed and divide by 24. This will give percentages greater than 100 for some of the sieves in beds deeper than 24 inches. The coarse material does not influence the effective size and this is without significance. Plot the computed percentages on logarithmic probability, or logarithmic paper the same as heretofore and determine the effective size in the manner described. The effective size so determined then takes into consideration the depth of the material, and is nearer the true effective size than if depth of bed is ignored. Table 4 gives the results on effect of varying the depth of the filter bed on lengths of filter runs. Material of the same size was used in the 4 filters. Using the computed sizes as effected by depth, and the filtration equation, the lengths of filter runs are very close to the computed runs.

DETERMINING THE EFFECTIVE SIZE OF SAND IN FILTERS IN SERVICE

There is difference of opinion as how best to determine the effective size of the sand in filters which are in service. This is of especial importance where there has been some loss of the material by washing, or where the beds have been washed to stratify the sand and some of the fine material at the top is removed. Various methods have been used to determine the size of the filtering material in beds in service. Some have attempted to collect a representative sample from the entire depth of the bed, while others have sampled the bed at the surface by taking a sample from the surface to some definite depth below the surface. The author is of the opinion that the latter is the best procedure, though it is important to know something of the size of all of the material in the bed. Assuming no change in the amount and character of the suspended material in the water, the sand in the top few inches of the bed determines the rate at which the filter will clog. The lower material, however, serves a useful function in preventing small amounts of coagulated material from passing through the bed.

A study of the sieve analysis of filtering materials from the top of the bed to various depths below indicates that the top 6 inches of the bed determine the clogging rate for most materials fine enough to remove all of the coagulated matter from the water. This does not imply that all of the fine material is in the top 6 inches. Table

TABLE 5

Screen tests of sand from various depths of filter S-4

Muscatine sand

PORTION OF BED	PERCENT PASSING SIEVES					
	20 .984 mm.	24 .748 mm.	30 .557 mm.	40 .429 mm.	50 .330 mm.	60 .261 mm.
Top 2 inches	100.0	99.7	85.7	15.9	0.26	0.00
2 to 4 inches	100.0	99.2	57.0	1.75	0.02	0.00
4 to 6 inches	100.0	95.8	21.5	0.36	0.02	0.00
Top 6 inches	100.0	98.3	54.3	5.87	0.09	0.00
6 to 12 inches	100.0	78.9	11.6	0.22	0.00	0.00
12 to 25 inches	99.0	55.7	5.28	0.14	0.00	0.00
Whole Bed	99.6	71.7	17.90	1.66	0.03	0.00

TABLE 6

Sieve analysis of top 6 inches of Muscatine sand from filter DX-2

Total of 3 sieved portions

SIEVE	GRAMS RETAINED ON SIEVE	TOTAL GRAMS PASSING SIEVE	PERCENT PASSING SIEVE
16	0.0	313.3	100.0
20	0.0	313.3	100.0
24	4.2	309.1	98.7
30	152.1	157.0	50.2
40	140.8	16.2	5.2
50	15.0	1.2	0.4
60	1.0	0.2	0.06
80	0.1	0.1	0.03
Less than 80	0.1		

2 Percent Size	0.385	mm. dia.
4 " "	0.420	" "
8 " "	0.445	" "
16 " "	0.475	" "
30 " "	0.510	" "
60 " "	0.570	" "
90 " "	0.655	" "

Average of 2 to 60 percent diameters	0.468 mm.
" " 2 to 90 " "	0.494 "
Percent of material of diameter less than 1.5 times the 4 percent size	84
Diameter of the effective size of the sand	0.489 "

5 gives sievings of the material of a filter bed at various depths, and shows that there is not complete stratification.

Collecting Samples from Filter Beds. The sampling device illustrated in Figure 3 is suitable for collecting the sample from the top 6 inches of the bed. Drain the water from the filter and collect samples at several places. These samples should be mixed into one sample, washed to remove dirt and mud balls, dried at 100 to 110

TABLE 7

Effective size of filtering material

Determined by sieving sample of whole bed and sample from top 6 inches of the bed

SAMPLE	HAZEN METHOD			IMPROVED METHOD			
				Whole bed		Top 6 inches	
	Effective size (10 percent)	60 percent size	Uniformity coefficient	Effective size	Effective size range	Effective size	Effective size range
	mm.	*mm.*		*mm.*			
M-2	1.94	2.42	1.25	1.78	23	1.674	27
N-2	1.33	1.67	1.25	1.27	95	1.277	95
Y-1	0.87	1.05	1.21	0.854	85	0.899	96
P-2	0.77	0.88	1.14	0.738	89	0.725	99
Q-2	0.555	0.65	1.17	0.543	95	0.556	100
R-2	0.444	0.501	1.13	0.434	99	0.436	100
S-2	0.290	0.357	1.23	0.279	38	0.281	97
T-2	0.243	0.280	1.15	0.235	94	0.245	95
J-3*	0.588	1.300	2.21	0.632		0.632	30
FX-2	0.383	0.755	1.93	0.370	27	0.360	90
GX-2	0.418	0.79	1.87	0.403	29	0.395	93
HX-2	0.490	0.77	1.57	0.477	34	0.485	82
D-5	0.539	0.834	1.55	0.527	37	0.540	82
Z-3	0.644	0.931	1.45	0.582	18	0.603	83
JX-2	0.870	1.80	2.07	0.877	32	0.876	70
LX-1	1.15	2.45	2.13	1.031	16	1.035	60
MX-1	1.93	3.17	1.64	1.62	11.5	1.582	42
JX-3	0.520	0.66	1.27	0.503	54	0.488	98
EX-3†	0.499	0.705	1.41	0.475	28	0.471	70
D-6	0.440	0.560	1.28	0.272	8	0.272	8

* Anthracite coal.

† Copley (crushed quartz).

degrees C., thoroughly mixed, and divided by splitting into halves until a sample between 100 and 200 grams is obtained.

Procedure for Determining the Effective Size. Sieve the sample in the manner previously described, plot on logarithmic probability or logarithmic paper, and determine the 1, 2, 4, 8, 16, 30, 60, and 90

percent sizes. Multiply the diameter of the 4 percent size by 1.5 to determine the effective size range. Obtain the average of the various sizes, unless one or more of the sizes is greater than the figure obtained by multiplying the 4 percent size by 1.5. In case 1.5 times the 4 percent size is less than the 90 percent size use the sizes in the average from the 2 percent size up to the size range, following the procedure given for a sample of the entire bed in taking into consideration figures between any two of the percent sizes.

Table 6 gives sieve analysis of a sample of sand from top six inches of a bed. This is the same material given in Table 2 for the analysis of the entire bed. The sizes determined by the two methods are the same though there usually is some difference. Table 7 gives the analysis of the sand used in a few filter beds in which sieve analysis was made of representative portions of the material before being placed in the beds, and the top 6 inches after the filters had been in service a short time. There is only a slight difference in the sizes determined by the two methods, indicating the procedure is reasonably accurate. When 1.5 times the 4 percent size gave a size range of over 90 percent of the material, it was necessary to include the 1 percent size in the average.

EFFECT OF THE SHAPE OF THE FILTERING MATERIAL

The main effect of the shape of the grains of filtering materials is the porosity of the bed. The porosity is that portion of the volume of the bed not occupied by the filtering material itself. The granules of filtering material are not packed together as closely as is possible for them to be packed, for they settle back into position after the bed is washed so rapidly there is not time for the grains to arrange themselves very compactly. Even then they would not settle back as compactly as is possible to arrange the grains in the bed by jarring it. The nearer the material is perfect spheres, the more compact will be its settling after washing.

Percentage of Voids. The percentage of voids in a filter bed as it settles after being washed varies from about 40 to 42 percent for the most rounded sand grains to 50 to 55 percent for angular materials such as crushed quartz and crushed anthracite coal. Table 8 gives the percent porosity of a few filtering materials as determined by the procedure which will be given.

Determination of Percent Porosity. The porosity should be determined in a manner typical of the porosity actually existing in

filter beds, however, it is not practical to measure the porosity of the material in place. Hulbert and Feben (11) developed a method of determining the porosity by use of the long glass tube of the Jackson Candle Turbidimeter. 150 grams of the sand are added to the tube half full of water. The tube is then completely filled with water and a stopper inserted so that there will be little or no air space. The tube is inverted and held until all of the material

TABLE 8

Materials used in tests on various kinds of materials

FILTER MATERIAL	DEPTH OF BED	EFFECTIVE SIZE	EFFECTIVE SIZE RANGE	SPECIFIC GRAVITY	POROSITY
	inches	*mm.*			*per cent*
DX-1 Muscatine Sand	24	0.444	9.0	2.65	42.1
EX-1 " "	21	0.257	7.5	2.65	44.0*
J-3 Anthracite Coal	24	0.632†		1.63	50.9
T-3 Crushed Quartz	24	0.453	12	2.61	52.9
DX-2 Muscatine Sand	24	0.489	28	2.65	45.1
EX-2 Crushed Glass	16	0.515	5.6	2.45	55.2
FX-3 Muscatine Sand	16	0.482	8.5	2.65	43.5*
EX-3 Crushed Quartz	24	0.475	28	2.61	52.7
HX-3 Rice Coal	24	0.457	22	1.60?	55.1?
2-4 Crushed Glass	24	0.547†		2.45	54.7
JX-3 Ottawa Sand	24	0.503	54	2.66	41.6
FX-4 Minchar	24	0.509	59		56.0*
GX-3 Coconut Char	24	0.515	52		53.0*
D-6 Ottawa and Berkshire Sands	24	0.272	2.4	2.66	42.0*
D-7 Iron Ore	24	0.359†		3.23	55.0
GX-4 Magnetite	24	0.465†		4.97	52.0
M-3 Iron Oxide	24	0.367?	14	4.93	55.7
S-4 Muscatine Sand	24	0.502†	39	2.65	40.8*
T-4 Muscatine Sand	24	0.502	39	2.65	44.4

* Estimate.

† Probable actual effective size.

settles. It is then rotated 180 degrees to an upright position and held as near as possible in a vertical position. The material dropping to the lower part of the tube stratifies itself somewhat in the manner that it does in a filter bed. This is a very simple method, but does not duplicate exactly the porosity of the bed when it settles back after being expanded by washing.

The procedure which seems most satisfactory is to use a glass

tube as shown in Figure 5. The tube has a rubber stopper with wire screen at bottom having openings small enough to prevent the material being tested going through. Such an arrangement gives excellent distribution of the water when being passed through to expand the material the same as is done in washing a filter. A graduated scale is fastened to the outside of the tube. A carpenter's rule three or four feet in length is satisfactory. It is important that the bottom of the rule be on an exact level with the wire screen, or that the distance to the exact level be known. The glass tube has to be calibrated accurately. This may be done by filling the tube to some height with water which will be above the depth of material to be tested. Withdraw water into a cylinder graduate, noting the volume at one-inch intervals. The volume between the wire screen and any height then may be determined accurately.

A sample of sand or other material which has been dried and weighed is then placed into the tube. The specific gravity of the material must have been determined previously. The tube should be filled to approximately 24 inches in depth. Water should be passed through the tube at a rate which will expand the material about 50 percent for at least 5 minutes. The water then is cut off slowly—the rate of cutting off being such that the flow is stopped completely within 30 seconds. A little practice will enable one to do this with considerable uniformity in the reduction of flow. From the height of material in the tube, the volume is determined. The weight and specific gravity gives the actual volume of the solid material. This subtracted from the total volume gives the void volume. The percentage then is determined by dividing the void volume by the total volume. This method should give close duplication of the porosity of the beds in large filters. Comparing porosities obtained in this manner with the method used by Hulbert and Feben, they are somewhat less.

As the top few inches of a filter bed do most of the filtering, there is question as to whether a sample of the material representing the entire bed should be used, or whether only the finer material should be used. For rounded filter sand, a sample of the entire bed will give close results, though for crushed materials this may not be the case. The sample should come from the top six inches of a bed of the material which has been expanded by washing. Where the material in a filter in service is to be tested, the sand sampler shown in figure 3 may be used to collect the sample. A representative

TABLE 9

Measurement of the size of sands with the microscope

Comparison of shape ratio with porosity

CRUSHED QUARTZ COPLEY, OHIO		ROUND SAND OTTAWA, ILL.		SUBANGULAR SAND MUSCATINE, IOWA	
Longest Diameter	Middle Diameter	Longest Diameter	Middle Diameter	Longest Diameter	Middle Diameter
mm.	mm.	mm.	mm.	mm.	mm.
1.8	1.3	1.7	1.4	2.1	1.6
3.2	2.3	1.6	1.4	1.5	1.2
2.0	1.5	1.4	1.3	1.0	0.7
2.4	1.3	1.4	0.9	1.4	0.9
2.9	1.4	2.5	1.2	1.4	0.9
2.6	1.2	2.6	1.3	1.2	0.8
3.7	1.7	2.0	1.5	2.1	1.7
1.8	1.6	1.5	1.3	1.3	1.1
2.2	1.2	1.3	1.1	1.4	1.2
3.2	1.7	1.4	0.9	1.7	1.4
2.9	1.6	1.2	1.1	1.2	0.7
1.4	0.9	1.2	1.0	0.9	0.7
1.7	0.9	1.4	1.2	1.8	1.2
2.7	1.7	1.4	1.3	1.4	1.2
2.2	1.5	1.6	0.8	1.1	0.6
1.7	1.1	1.4	1.3	1.4	1.1
1.8	1.2	1.3	0.9	1.2	0.9
2.2	1.4	1.3	1.2	1.0	0.7
1.7	1.4	1.5	1.4	1.4	1.3
1.3	1.0	1.6	1.3	1.8	1.5
2.7	1.4	1.5	1.2	1.0	0.6
2.3	0.7	1.8	1.4	1.6	1.0
1.4	1.1	1.5	1.1	1.7	1.2
2.4	1.3	1.6	1.2	1.6	1.2
1.6	0.8	1.7	1.2	1.3	0.8
2.4	1.4	1.7	1.4	1.6	1.4
2.4	1.6	1.3	1.0	2.4	1.6
2.7	2.2	1.1	0.8	1.7	1.5
2.3	1.3	1.6	1.4	2.5	1.7
2.1	1.4	1.6	1.4	1.0	0.7
Average 2.26	1.37	1.56	1.20	1.49	1.10
Shape Ratio	1.65		1.30		1.355
Porosity	52.9		41.6		42.1
Porosity ÷ by Shape Ratio	32.1		32.0		31.1

sample of the material should be washed to remove all the foreign substances, dried, and the specific gravity determined before making the porosity test; but do not use the washed and dried material for making the porosity test.

Shape of Material. There is considerable difference in the shape of sand and crushed materials. There is question as to whether any factor other than size as determined by sieve analysis, and porosity should be taken into consideration in specifying a filtering material. With such materials as are now being used for filter beds, the belief is that this gives enough information about the material, except the requirement frequently inserted in specifications that the material be free from flat particles is a good provision. The microscope is the best means of determining the shape of the material.

Spread a representative sample of the material on a glass slide, spreading the grains so that very few of them touch each other. Most of the particles will arrange themselves so that the shortest diameter is approximately in a vertical position. The microscope should be equipped with micrometer for measuring depth. Focus on the highest part of the particle, then on the glass side. The difference will give the shortest diameter of the particle. The middle and longest diameters are determined by the micrometer in the eyepiece. Photomicrographs or camera lucida drawings also may be used, but depth of the particle is not obtained in this manner.

Some relation was obtained between the porosity of sand and crushed quartz when compared on the basis of the ratio of the middle diameter to the longest diameter. This relation, however, did not hold for flat material. Table 9 shows the relation between crushed quartz, a rounded sand, one not quite so rounded. When the percent porosity is divided by the diameter ratio approximately equal figures are obtained, indicating there may be some such relation. Measurement of the middle diameter of rounded sand, which is the shortest diameter of the material observed when spread out on a microscopice slide, has been found to give a diameter nearly equal to that of a sphere of the same volume. The microscope may be used for determining the effective size of filtering materials (12), though such a procedure is not recommended where it is possible to make sieve analysis.

RELATION OF SAND SIZE TO LENGTH OF FILTER RUN

The effect of the size of filtering material on length of filter run has been published (13) and will be mentioned only briefly. Experi-

ments covering a period of over two years were run on filtering materials varying widely in size at the Chicago Experimental Filtration Plant. The experiments not only included materials varying in size, but the uniformity of the material was varied from sets of filters where the material was very uniform in size to materials which were not uniform. A summary of the results is given in table 10. Figure

TABLE 10

Effect of size of sand on length of filter run

FILTER NUMBER	DURATION OF TEST	EFFECTIVE SIZE	EFFECTIVE SIZE RANGE	AVERAGE LENGTH OF FILTER RUNS
		First series of tests (1929–1930)		
	months	*mm.*		*hours*
N-1	13	0.307	13	15.5
P-1	13	0.400	45	29.9
Q-1	13	0.422	34	36.7
R-1	13	0.430	28	37.3
M-1	13	0.515	38	58.9
O-1	13	0.568	40	71.7
		Second series of tests (1932–1933)		
FX-2	12	0.370	27	12.8
GX-2	12	0.403	29	16.9
HX-2	12	0.477	34	25.0
D-5	12	0.527	37	34.9
Z-3	12	0.582	18	42.0
JX-2	12	0.877	32	83.6
LX-1	12	1.03	16	123.7
MX-1	12	1.62	11.5	348.7
T-2	12	0.236	94	4.6
R-2	12	0.434	99	21.0
P-2	12	0.735	89	62.5
N-2	12	1.270	95	219.0
EX-1	9	0.257	7.5	8.6
DX-1	12	0.444	9	23.0

6 shows plotting of the results on logarithmic paper. A line passing through the points has a slope of approximately 2.15, indicating that the length of filter run varies approximately as the 2.15 power of the effective size of the sand when the effective size is determined by the improved method of determining sand size. All of these materials were natural sands and there was not enough difference in the porosity to effect the results materially. Having a definite

relation to diameter, an equation may be used for computing the length of filter run, if the run on one filter is known.

$H = KD^{2.15}$

H = Hours filter runs

K = Filtration Constant (must be determined experimentally)

D = Diameter of effective size of the filtering material in mm.

These data must not be construed as meaning that each filter run was of such close relation. Runs occasionally varied considerably from the line given, but the average of the results over a long period showed this relation. If examined for certain seasons of the year, temperature of water, or character of suspended matter, relations for one condition may differ slightly from that of another.

The results given in table 10 and shown in figure 6 should not be construed as giving the clogging rate to be expected with a certain size of filtering material. The character and amount of coagulated matter going to the filters varies widely the clogging rate for a given size of sand. The only way the data may be used is that when the clogging rate is known for a certain size of sand, the rate on a bed with sand coarser or finer can be computed. As the clogging rate on a filter may be changing almost hourly, the computed rate would apply only at the time the other filter is being run. The effect of sand size applies to filter beds which are kept clean, and to where surface cracks and pulling away from the sidewalls of the filters are prevented. Cracks extend the surface area of the filters, and beds with fine sand usually crack to a greater extent than coarse sand, so the relation given will not hold for beds which form cracks at the surface.

THE PROCESS OF FILTRATION

This applies to the filtration through rapid sand filters of water which has been coagulated with chemicals in the manner now generally used in water purification plants. The coagulated matter which goes to the filters is largely the smaller and lighter flocculated particles, for most of the heavier particles usually settle from the water before it reaches the filters. Observation of filtration in a glass slide filter reveals that the coagulated matter, after following the water to the filter surface, either comes to rest on the surface of the bed, or passes beneath the surface through the openings between the grains of sand. Sand will be assumed to be the filtering material, however, the description of filtration will apply to other materials.

In passing beneath the surface, the large flocculated particles, if any are present, are broken up into smaller particles.

Where Filtration Takes Place. Much of the coagulated matter in the water passes into the filter bed through thousands of openings in each square foot of the filter surface and is filtered out largely in the top inch of the bed. When a filter is placed in service after washing, nearly all of the coagulated particles at first pass into the be if the sand is of the size generally used for rapid sand filters. As the coagulated matter lodges between the sand grains beneath the surface the free void area becomes restricted and offers resistance to the flow of the water. Conditions then begin to change. The rate of flow increases through the larger openings and lessens through the smaller and partly clogged openings. Many of the larger passageways are kept almost free of deposited material by the rapid velocity of the water. As filtration continues the smaller openings become so clogged with the coagulated matter they are almost closed, and the coagulated matter then comes to rest at the surface of the filter above the clogged areas. The number of openings at the surface per square foot of filter area is still very large, and there may not be an area as much as one-fourth square inch without a hole. Gradually many of these holes become clogged by the voids beneath the surface becoming so clogged the flow is little.

Size of Voids Vary. Figure 7 is an attempt to represent an area of the surface of a sand bed about 4 mm. square. Most of the grains are close together, though there are places where the openings are much larger than the average size opening. This is caused by the sand not compacting itself to the maximum density as it settles after washing. Probably the upward flow of the water just as the sand grains are coming to rest tend to push some of the grains aside and aid in the formation of some of the passageways larger than they otherwise would be. There is no direct proof, however, of this assumption. Sand settles back after washing with about 41 to 45 percent voids, whereas it may be compacted by jarring to about 39 percent voids. This increase of the voids over the maximum compactness is not evenly spaced around each sand grain, so it represents increases in the size of some of the openings in numerous places throughout the bed greater than the average increase in the void volume. Figure 7 shows such an opening at the surface of the sand, and there are numerous places throughout the bed as large or larger.

Channels are Formed. These larger openings at the surface form passageways considerably larger than the average passageway, and it is not likely that such an opening will become filled with coagulated matter if the large area extends any distance into the bed. The water rushes through such openings much more rapidly than it does through the smaller openings where the bed is more compact, even at the beginning of the filter run. This may be demonstrated by adding coloring matter to the water just above the sand in a glass side filter and observing how quickly it passes a short distance into the bed. No opening of this kind should be expected to extend deeply into the sand bed, and the coloring matter may not appear at the bottom of the sand in a time much shorter than that necessary for theoretical displacement of the voids, for the channels usually are short. This, however, does not indicate uniform flow through the bed.

A fine stream of coloring matter added at the surface of a glass side filter may not spread more than $\frac{3}{4}$ to 1 inch in width by the time it reaches the bottom of a bed 24 inches in depth, showing that the water follows a fairly straight course downward, unless there is variation in the size of the sand grains or other conditions to cause the flow to be deflected. A small amount of coloring matter added at the surface of a filter extends into a column of colored water 6 to 10 inches long by the time the lowest part of the column in 24 inches below the surface, showing that it has spread considerably in the vertical direction. Figure 8 illustrates an enlarged passageway or channel from the top of the bed downward for the depth of a few grains of sand. The channelizing effect at the surface of a filter bed where there is some penetration of the coagulated matter into the bed may be observed with glass side filters by use of a strong reading glass or a low power microscope. It also may be observed by adding coloring matter to the water just above the sand surface and watching the streams of color shoot rapidly down the distance of one to two inches, depending on the penetration of the coagulated matter into the bed. In a filter partly clogged, where the time required for the water to pass through a 24 inch bed in 3 minutes, the coloring matter may shoot downward one inch in less than one second and a distance of two inches within 3 to 4 seconds, each inch of travel should require about 7.5 seconds. The flow through the channels therefore is many times that of the average flow, and is another proof of channelizing in the upper part of the bed.

How Coagulated Matter is Filtered. Figure 8 illustrates how the coagulated matter is caught in the sand. The wedge shape of the void where two sand grains touch is the lodging place of the coagulated matter first removed from the water. Nearly all of the particles of coagulated matter at the beginning of the run lodge within such places before the water has passed one-half to one inch below the surface. Both the wedge shape of the void and accumulated coagulated matter aid in lodging other particles of coagulated matter in the same places, and soon to the extent that there is resistance to the flow of water.

If the sand grains are small in size, or the coagulation is tough, there may not be much accumulation of coagulated matter beneath the sand surface before the openings are closed to the extent that not much of the coagulated matter passes beneath the surface. This is shown by the illustration on the left in Figure 9. The center illustration represents penetration of part of the coagulated matter into the bed with a fairly large portion of it remaining at the surface. The illustration on the right represents continued penetration into the bed through channels. The illustration in the center and the one on the right represent conditions which are expected to take place in a rapid sand filter bed. The penetration of coagulated matter should not be great, though it should be from 2 to 4 inches in order to obtain reasonable length filter runs. Where there is little penetration of the coagulated matter into the filter bed as shown by the illustration on the left, the loss of head increases rapidly and the filter runs are too short for practical operation of the filters.

There is little or no depositing of coagulated matter from the swift currents of water in channels as illustrated in figures 8 and 9, but when the flow reaches sand in which the voids have not been filled with the coagulated matter it spreads out to where the velocity is not great, and lodgement of the material takes place where the grains touch. When the voids in the sand around the end of the channel become filled to the degree that considerable resistance to the flow takes place, channels then may open up through the clogged portion to throw the water into places where there is little or no clogging. The water spreads out and decreases in velocity to the degree that the coagulated matter is removed by lodging between the sand grains, repeating the process above described.

The loss of head continues to increase on the filter, and the channels through the surface become fewer as the coagulated matter

clogs to greater depth. Also the channels become longer, and much of the loss of head taking place through the filter bed is friction of the water in passing through the channels. Frequently within areas where there has been no hole through the surface for some time the increased pressure due to the increasing loss of head may cause holes to open. How much of the flow of water, after the loss of head has increased 6 to 7 feet, passes through the surface of the bed in channels, and how much passes directly through the layer of coagulated matter is not known. It should be evident that some passes through the layer at the surface, though it is believed that decidedly the greater portion is passing through the holes with sand of the size most generally used.

Continued penetration of the coagulated material into a filter bed is not by the material removed at or near the surface being forced deeper into the bed. It is by the water which is being filtered largely by passing the clogged portion of the bed through channels, and the coagulated material which is in this water not being filtered until the water spreads from the channels below the clogged layer. The velocity as it spreads is checked to a rate of flow which will allow lodgement of the particles between the sand grains. Some of the material previously lodged in the upper part may break loose and be forced below the clogged portion, but most of the material at the lower part of the clogged layer when it is more than about one-half inch thick has been carried there directly with the water. Assume a filter has been run until the loss of head is high and the clogged layer is about two inches thick, then if water coagulated with some other substance which produces a different color of precipitate is substituted, some of the new material will be observed at the bottom of the clogged layer very shortly after the change.

Figure 10 is photograph of several square inches of the surface of a filter bed showing holes through the surface layer. The water, after the filter had reached about 8 feet loss of head, was drawn down to about 3 inches above the sand and the camera pointed straight downward. All of the dark spots in the photograph represent holes, and there may have been a few others which do not show. The photograph is slightly enlarged from natural size, and it shows that there is scarcely a square inch of the surface in which there is not a hole. The holes shown in figure 10 are the type holes illustrated in figures 8 and 9. Such holes occur probably only where there is an opening at the surface somewhat as shown in figure 7.

There was no way of telling how deep the holes extended into the bed, but some of them may have extended as deep as two inches or more.

RATE OF FILTRATION

For many years it has been customary to rate rapid sand filters at 2 gallons per square foot per minute, or 125 million gallons per acre per day. So many plants now use higher rates of filtration during peak demand there is doubt if any rate should be given as the rated capacity. Perhaps the best method of expression is to state the capacity of the filter in gallons per day on the basis of the two-gallon rate, calling it the usual or nominal rating. Then if a filter is operated at a rate of 2.4 gallons per square foot per minute it is operating 1.2 times nominal rating. This is better than saying it is operating at 20 percent overload, for if it is filtering the water properly it is not overloaded. A filter operating at 1.8 gallons per square foot per minute then should be stated as operating at 0.9 nominal rating.

Effect of Rate of Filtration on Length of Filter Run. Experiments conducted on varying the rate of filtration at the Chicago Experimental Filtration Plant indicate that the runs vary inversely approximately as the 1.5 power of the rate. Selecting certain periods, the runs will be found to vary inversely as the 1.2 to 2.0 power of the rate. The experiments were conducted on steel filters having surface areas of 10 sq. ft., and on glass tube filters having surface areas approximately 2.5 sq. in. On the basis of these experiments, it is difficult to set an exact effect of the rate, though it is believed the figure of 1.5 for the average of all runs is near enough the correct figure for practical uses. An account of the effect of rate of filtration on lengths of filter runs has been published (14).

One probable reason why it is difficult to obtain more uniform data on the effect of the rate upon the length of run is due to the flocculated matter penetrating to different depths in the bed as the rate is varied. It appears that some of the water is gradually squeezed out of the coagulated material after it deposits in or at the surface of the sand bed, and that time is required for this to take place. When a large amount of the coagulated matter goes to the filter within a certain time, due either to a high concentration in the water or a more rapid flow of the water, there is not time for the coagulated matter to be compacted to its maximum density.

This is mentioned as a possibility without positive proof that it is the main cause of the variations in the results.

The effect of the rate of filtration on the length of filter run may be expressed by the equation

$$H = \frac{K_1}{B^{1.5}}$$

H = hours filter runs.

K_1 = constant, depending on the clogging tendency of the water.

B = rate of filtration in gallons per square foot per minute.

TABLE 11

Effect of the rate of filtration

FILTER RATE GAL. PER SQ. FT. PER MIN.	INITIAL LOSS OF HEAD FEET	TURBIDITY FILTER EFFLUENT	BACTERIA PER CC. 37°	B. COLI 100 CC.	FILTER RUNS	
					First test 13 months	Second test 5 months
					hrs.	*hrs.*
1.6	0.80	0.059	63	3.5	25.7	
2.0	0.96	0.065	54	3.6	20.7	31.7
2.4	1.12	0.080	57	4.7	15.4	
2.5						19.1
2.8	1.27	0.096	66	4.8	11.7	
3.0						16.6
3.2	1.36	0.090	48	5.6		
3.5						13.4
Water before filtration.....		7.68	88	13.3		

This equation does not tell much, for the length of run at one rate has to be known, however, when the run at one rate is known the length of run at any other rate may be computed. The computed run may not be exact, though it is close enough for practical purposes.

Effect of Rate on Initial Loss of Head. In a series of tests on filtration rates covering a period of 13 months the initial loss of head was measured. This is given in Table 11. This initial loss was through 24 inches of sand and 18 inches of gravel. The effective size of the sand was approximately 0.5 mm. The loss through the underdrains was not included.

Effect of the Rate on the Quality of the Filter Effluent. Table 11

shows that there was a slight depreciation in the quality of the water, though not enough to be serious. It might be well to state that there was not a period of weak coagulation during the course of the experiments. The bacterial counts on the water going to the filters were low, and as the water carried an abundance of microscopical organisms the bacterial efficiency was low. The effect of rate of filtration on the bacterial results covered only 4 months, for the balance of the time the water was prechlorinated. Had the experiments been conducted during a period of weak flocculation, the effect of rate very likely would have been more evident. The author wished to warn that the bacterial results should not be taken as typical of all waters. They apply to the particular water and the treatment being given it at the time of the experiments. This also is the case of the turbidity of the filter effluent.

SUMMARY

A review of past experiences in filtration shows there has been rapid development in the treatment and filtration of water.

Improvement in the washing of filters has been slow, caused by the belief that future developments in the design of filter bottoms will eventually produce satisfactory cleansing of the beds. This hope has not been realized and the use of some force to assist the washing is essential. A surface washing system is the best and cheapest means of obtaining this extra force.

A submarine light in the filtered water reservoir to observe the clarity of the water is a very helpful means of determining if the water has been treated and filtered properly.

Most of the filter bed clogging troubles are caused by failure of the washing system to remove from the filter all of the material filtered from the water.

Measurement of the volume of mud balls in the filters gives good indication of the effectiveness of the washing system in keeping the beds in excellent condition. A procedure for measuring the volume of mud balls is given.

A filter is in excellent condition when the volume of mud balls in the top six inches of the sand is not more than 0.1 percent of the volume of sand. When the volume is more than 0.2 percent, extra washing facilities should be installed. A filter in which the volume of mud balls is more than 2.5 percent should be classified as being in bad condition.

An improved method of determining the effective size of filtering materials is described. The size is based upon the average of the 1, 2, 4, 8, 16, and 32 percent sizes. The percent size means the material by weight that size and finer. The effective size range is determined by finding the weight of material smaller in size than 1.5 times the diameter of the 1 percent size. When the effective size range is less then the 32 per cent size, no material greater in size than that included in the range is used in determining the effective size.

A procedure somewhat similar is recommended for determining the effective size of the material in filters which have been in service. Samples of the sand are collected from the top six inches of the bed and sieved and a wider size range is used. This procedure is advantageous where some of the fine material has been scraped from the top of the bed after the filter has been washed, and also where there has been some loss of the fine material by washing.

The effect of the depth of the filter bed on the effective size is described.

The shape of the material effects the porosity of the bed. A procedure for determining the percent voids under conditions similar to that of the material in service in filters is given.

Experiments extending over long periods indicate the effect of the size of filtering materials on the length of filter runs varies approximately as the 2.15 power of the diameter of the effective size of the material.

The process of filtration is explained. Most of the filtration takes place at the surface of the bed, and one to two inches below the surface. As the pores at the top of the bed become clogged, much of the water passes the clogged layer through numerous small channels. Filtration of the coagulated matter from the water which passes through the channels takes place after the rapid flow has been checked beneath where the bed is channelized.

The coagulated material which passes beneath the surface of the bed is filtered largely by lodgement of the coagulated particles in the wedge-shaped parts of the void where two grains of the material touch.

Numerous holes through the layer of coagulated material filtered at the surface of the bed frequently are readily visible when the filter has been in service for some time after washing.

Two gallons per square foot per minute should be considered the

nominal rating of filters. Rates higher or lower should be designated by a figure which when multiplied by the nominal rating will give the rating in terms of the nominal rating. A rate of 2.4 gallons is 1.2 times nominal rating.

The length of filter run varies inversely as approximately the 1.5 power of the rate of filtration.

There is a decrease in the efficiency of the filter as the rate of filtration is increased above the 2-gallon rate, but the decrease is not great for some waters until the rate is increased above about 3 gallons per square foot per minute.

Acknowledgement. The writer wishes to express his appreciation to Loran D. Gayton, City Engineer; and Arthur E. Gorman, Engineer of Water Purification; Bureau of Engineering; Department of Public Works; City of Chicago; for permission to publish this paper. Most of the experimental data given were obtained at the Chicago Experimental Filtration Plant.

REFERENCES

1. Fuller, G. W. Progress in Water Purification. Jour. A. W. W. A., **25**: 1566 (1933).
2. Fuller, George W. *The Purification of the Ohio River Water at Louisville, Kentucky.* D. Van Nostrand Co., New York (1898).
3. Ellms, J. W., and Hauser, S. J. Ortho-tolidine as a Reagent for the Colorimetric Estimation of Small Quantities of Free Chlorine. Ind. and Eng. Chem., **5**: 915 (1913).
4. Wolman, A., and Enslow, L. H. Chlorine Absorption and the Chlorination of Water. Ind. and Eng. Chem., **11**: 209 (1919).
5. Baylis, John R. Sand-bed Studies at Montebello Water Filters, Baltimore. Eng. News-Rec., **92**: 516 (1924).
6. Baylis, John R. Filter Bed Troubles and Their Elimination. W. W. Eng., **89**: 1358, 1424, 1486, 1542, 1610 (1936).
7. Hazen, Allen. Some Physical Properties of Sands and Gravel. Report of the Massachusetts State Board of Health, p. 550, 1892.
8. Burgess, Philip. Mechanical Analyses of Sands. Jour. A. W. W. A., **2**: 493 (1915).
9. Tyler, Richard G. A fineness Modulus for Filter Sand. Eng. and Cont., **65**: 827 (1925).
10. Anon. Filter Sand and Effective Size. Eng. News-Rec., **106**: 770 (1931).
11. Hulbert, Roberts, and Feben, Douglas. Measuring Porosity of Sand. W. W. Eng., **87**: 18 (1934).
12. Report of the Committee on Filtering Materials. Jour. A. W. W. A., **24**: 1316 (1932).
13. Baylis, John R. A Study of Filtering Materials for Rapid Sand Filters Part 2, W. W. and Sew., **81**: 162 (1934).
14. Ibid., Part 3, 352 (1934).

PUBLIC SAFETY AS RELATED TO WATERWORKS OPERATION*

By T. W. Coleman

(Resident Engineer, City Water Co., Chattanooga, Tenn.)

Self preservation or personal safety is said to be the first law of nature. Safety has been important to man since the very beginning but never so important as it is today. Man will follow this natural law of self preservation to a certain extent but to consider safety to others must be trained. In this age of fast automobile and high speed machinery, safety must be taught and practiced from the cradle to the grave. Every day accidents take their toll of human lives from the fields of man's activities. The waterworks field is not exempt. The waterworks operator knows the value of safety within his own organization. Lost time, accidents and medical expense of his own forces are brought directly to his attention. The injuries suffered by the public from some neglected condition of his equipment is not always brought so forcibly to his attention. Too often claims for such injuries are settled by the company's lawyer or insurance adjustor and he never learns the details of the accident. He does learn, however, that such accidents cost money and for this reason if no other, public safety should be of great importance to him.

When the waterworks operator comes to consider public safety he has a very broad field. His pipe lines, services and meters cover the whole area served by his utility. His meter and repair trucks are constantly over the whole city. His reservoirs and standpipes are attractive nuisances to small boys. His office is visited monthly or quarterly by most of his consumers, and visitors come to visit his pumping stations and filtration plant. All of this equipment and properties can and does, without proper precautions, become safety hazards to the public. Of this equipment the curb meter and meter box are most important from a standpoint of public safety.

The winters of the southeast being comparatively mild and short the operators of water utilities in this section find the use of the curb meter setting very desirable. Since the frost line is shallow there is

*Presented before the Kentucky-Tennessee Section, April, 1937.

little danger from frozen services and the curb meter is accessible at all times for readings or repairs. While the curb meter installation has these very desirable features it also has because of its location the possibility of becoming a costly hazard to the public safety. A safety hazard for every meter installation.

In the city of Chattanooga we now have over 27,000 meter box installations. During the past ten years we have had approximately 300 lawsuits and claims for injuries suffered by reason of some negligent condition of our meter boxes. These suits amounted to several hundred thousand dollars. We fortunately did not lose all of these suits and many of the claims were settled quite reasonably. The cost of the first few lawsuits made us realize, however, that we must give our attention to public safety. We must make our meter box installations safe and be able to prove them safe in the law courts.

Prior to the year 1900 people generally were not so ready to have their wrongs redressed in the law courts. With the steadily increasing use of the automobile came the increase in the number of auto accidents. Disputes arose and it was necessary to go to court for satisfactory settlement. People became increasingly lawsuit conscious, spurred on by the liberality of the juries in awarding damages. Today it does not seem strange to hear some claimant say "You can pay me or I'll sue you." When you hear him say that, you can be sure he will sue if he has any case at all. It is no secret that juries always lean toward the individual in his suit against a utility company. Thus we go to court to defend a suit with the juries more or less prejudiced, and opposing attorneys fiery and venomous. I am sure my face has been very red many times in the court room listening to one of these lawsuit lawyers venting his spleen. I have heard the city Water Company of Chattanooga declared to be criminally and maliciously negligent, wantonly disregarding the safety of the people of Chattanooga, Shylocks and any other expression calculated to bring us in absolute disrepute before a jury of farmers. The majority of jurors in Hamilton County, as in nearly all counties, are selected from the rural section of the county. These men for the most part are honest and are inclined to take literally what the witnesses and lawyers say. If the plaintiff in the case is a woman they will believe her preferably and the verdicts will be high.

Napoleon was a great general, and one of his rules was never to fight with the same enemy too often lest he learn your method of fighting and set up defenses to defeat you. There were a group of

lawyers bringing these suits and they made the mistake of having us in court too often. We learned their method of preparation and attack and we began planning our defenses accordingly.

In Tennessee the plaintiff is required by law to furnish the defendant with a copy of his "Declaration." This "Declaration" shows the amount sued for, the cause of injury and why the plaintiff should be allowed to recover the defendant in a Court of Law.

These suits were mostly brought to recover for injuries through stumbling, tripping or falling over a curb meter box. In the declarations filed in these suits we found two allegations included in each one. Viz.; It is the duty of the Water Company to install and maintain its service appliances in a reasonably safe condition for the users of the streets and sidewalks of the City. The second allegation is as follows: The Water Company maintained said appliances in a negligent and careless manner allowing them to become dangerous, all of which is the cause of the plaintiff's injuries.

We consequently became more acutely conscious of our duty to the public to keep our equipment in a reasonably safe condition and that we would be penalized by the courts for a failure to do so. We did not wish to be penalized and in addition had an honest desire to keep our appliances as safe as possible.

The City Water Company of Chattanooga has always practiced safety to a certain degree. We found, however, that if we would stop losses from accidents, organized safety efforts would be necessary. In 1927 we formed our Safety Organization. A general safety chairman was appointed for a year with a safety committee composed of three employees, one of whom acts as committee chairman. A new man is added to this committee each month and one is dropped, so that each member of the committee serves for three months during one of which he acts as chairman. The duty of this committee is to make a complete safety inspection of the entire plant each month. The results of this inspection are brought up at the general safety meeting held by all department heads, foreman, truck drivers and others, at which time the points brought out by the safety committee are discussed and recommendations considered toward eliminating any hazards.

It was through the combined efforts of the members of this safety organization that we were able to reduce our public accidents from an average of forty a year to three in 1936. We have not had a single public accident so far in 1937. It might be profitable to some waterworks operators to know how this reduction was accomplished.

The meters of the City Water Company are read once each month by our readers. There being over 27,000 meters each meter reader must read an average of 300 meters in eight hours. To read this many meters in the allowed time, he must move rapidly. To assist him in this work is a helper or lid lifter. The monthly visit these men make to our meter settings are the only inspections made of these meters. In case of a suit or claim for injury these men are usually the last men of the company to have seen the meter box prior to the date of the injury. They, therefore, are your most important and sometimes sole witnesses for your defense. In reading as many meters as he does it would be next to impossible for him to remember the condition of any one particular box. If he should happen to remember the particular box in question it is not likely the jury would give much credit to his testimony. We had to bring these men to court with some definite evidence of their having inspected the particular box in question. In order to provide the necessary evidence we made a code sheet on which was itemized and numbered the condition of a meter or meter box which should be noticed. This code sheet has a total of twenty-one items but only six of them have a bearing on public safety. These six items cover the following conditions: broken meter boxes, meter box should be lowered, meter box should be raised, fill in around meter box, meter box lid missing, meter box lid defective. This code sheet was attached to each field meter reading book carried by the meter reader when reading meters. On each page of these field meter reading books a space was provided for listing these numbers and also the meter reader's name. When these field meter reading books are returned to the office a work order is made from these records of any bad condition of these boxes. These work orders are then given to the foreman of the repair crews who after correcting the condition return the orders to the office where they are filed in the service records. With these records in the hands of our meter readers and repair foreman as evidences to their testimony we were able to successfully defend many law-suits.

It was necessary in the beginning to school our meter readers to recognize at a glance whether or not a meter box was in an unsafe condition. To do this we made a general inspection of the meter boxes in every section of the City using a small movie camera to take pictures of the conditions which we wished them to recognize as needing repairs. Soon after this system was inaugurated we found to our surprise that meter box repair orders began to pile up. It was

sometime before the bottom of this pile was reached, but when we did get to the bottom order our claims for injuries had decidedly declined. So far to date we have worked over 28,000 meter box orders reported by the meter readers. A good many of these orders are repeat orders on the same meter box. In the unpaved sections of the City where the earth around the meter boxes is not supported by curb or sidewalk a light rain will sometimes wash the earth from around the meter box leaving it higher than the surrounding ground level.

There is one theory of law applicable to waterworks operation in connection with the condition of meter boxes which I wish to call to your attention. This is the theory of actual or constructive notice. A suit against a water utility by reason of someone falling or tripping over, or stepping in a meter box or curb box is a negligence or tort action. Before the plaintiff can recover he must show that the defective, dangerous or faulty condition causing his fall was due to the negligence of the water utility. This negligence may be an affirmative act in creating the condition complained of, or it may be a negative act, so to speak, or a failure to correct and remedy the said condition. It is very seldom that a complainant can prove an affirmative act of negligence. He can ordinarily only show that the condition was dangerous or defective at the time of the accident. He does not, however, have to show affirmative negligence for the trial Judge will charge the jury as follows: "Now gentlemen of the jury, even if the Water Company did not create the dangerous condition complained of, they may still be liable as it is the duty of the defendant Water Company to maintain its equipment in a reasonably safe condition. Even if some third party actually created this allegedly dangerous condition, the defendant Water Company would be liable if it had notice of this condition. Such notice may be actual or constructive. Actual notice means of course that the Water Company through its agents or servants actually had seen or heard of the dangerous condition. Constructive notice means that the dangerous condition existed for such length of time that the Water Company would and should have known of the condition had it exercised reasonable care. What length of time is necessary is for you gentlemen of the jury to determine after considering all the circumstances; the location of the apparatus, the density of pedestrian traffic, seriousness of the defect and its apparent danger." This constructive notice theory is the joker in this charge. A reasonable length

of time is very short when a meter box lid is missing from a meter setting on a crowded city sidewalk while in a less travelled section, one week probably would be reasonable time in which to make repairs in order to avoid liability. We also must depend to a large extent upon being notified by the public. The cost of making inspections of meter boxes more often than once a month as by the monthly meter readings would be prohibitive. A monthly general inspection of meter boxes as by meter readers has been held by the courts to be reasonable inspections if it is shown that the meter readers actually made an inspection.

The operators of water utilities should also take notice of the fact that a pedestrian using the city sidewalks is required to use only ordinary care for his own safety. When a water utility finds it necessary to set a meter box in the sidewalk paving it would be well for it to be sure this installation is safe as possible for pedestrians. In this same connection, however, if this same pedestrian decides to change the course of travel and turns toward the street and injures himself on a meter box set in the grass plot between the curb and sidewalk he is required to use a much higher degree of care for his own safety. He must be careful to look before stepping from the pavement. This law is well settled in Tennessee by the Supreme Court in the case of Ward vs. Western Union Telegraph Company.

The water utility often has as its defense the doctrine of contributory negligence which bars the plaintiff's right of recovery. If a meter box in front of a consumer's premises should become in a dangerous condition and the consumer takes notice of this condition, but does nothing about it and later forgetting the dangerous condition he himself is injured he is guilty of contributory negligence and he cannot recover of you for his injury. There are other ways in which the injured person may be guilty of contributory negligence such as by any act on the part of the injured which caused or helped to cause the dangerous condition.

These general rules of law should be well understood by waterworks operators because even with very able lawyers to defend him in court, his lawyer can only show to the court what the waterworks operator can tell him. The waterworks operator must know what information he must have in order to help prepare a defense. While the company lawyer probably should make the investigation of claims, they are often too busy to make such investigations and valuable evidence to your defense is never obtained. It is, there-

fore, almost imperative that the water utility make inspections of all claims and keep good clear records of these investigations.

In making investigations of injury claims, we have found that noting the following conditions has been necessary for our protection: It is important that the first notice of an injury be recorded as to time, date and way notice was received. We have received such notices on the telephone when the party giving the notice would not give their name. In some cases the first notice we receive of an injury was when suit was filed, which in most cases, is several months after the accidents causing the injury happened. In these cases the records made by the meter readers described above are most valuable. After notice is received, an inspection of the meter box or dangerous condition of the appliances reported should be made. If it is a meter box, it should be carefully inspected and the following questions answered. Is the meter box set level and the top of the box even with the surrounding ground making a continuous even surface? If not, measure and record difference stating whether box is high or low. Is high grass growing around box? Is the meter box or lid cracked or broken? Will the lid tilt downwardly in the box or move when stepped upon? Meter type and shape of meter box. Raise lid and notice if the adhering dirt or inside walls have been disturbed. Examine the earth in the bottom of the meter box for footprints and notice the top of the meter for scratch marks. If your notice is received very soon after the accident the above information will be helpful to you in determining whether the claim is brought in good faith or possibly fraudulent. It is always a good idea when possible to have someone with you when examining the box to corroborate your testimony in case you go to court. We have been fortunate at times in getting the consumer himself to be present during the meter box inspection. His testimony will carry more weight with the jury than another person from the Water Company. A rough sketch should be made showing the relative location of the meter box with reference to the curb, sidewalk, driveways and property line. A photograph of the box and its surrounding are very helpful in showing the jury the conditions you will testify to.

It is very important that the people living in the immediate neighborhood where the box is located be questioned to learn what they may know of the accident and condition of the box prior to the accident. The statement of these people should be reduced to writing. Have them sign these statements if possible. If some person is

claiming injury because of a missing meter box lid you may find a neighbor who can say that they saw the lid on the box the day of the injury or the day before. Here you can avail yourself of the defense that the dangerous or defective condition was unknown to you and that having existed only a day or so, not sufficient time had elapsed to charge you with constructive notice, of said condition.

Inspections of this kind are important for other reasons than planning a defense to a law suit. You will learn whether you have maintained a dangerous condition for which you are liable and in which case you often can make a very reasonable settlement of the suit out of court.

It might seem to some people that a very serious injury could not result from a meter box setting and for this reason, I wish to touch on a few of the injuries we have on record.

A lady well past middle age, while walking on the sidewalk caught her heel on an open meter box and fell backward on the corner of the curb, the base of her spine striking the curb. In addition to other injuries her pelvic bones were broken. She was confined to a hospital bed ten months with weights on her feet. She never fully recovered. Her injury was permanent. Other serious injuries have resulted when pregnant women have been caused to fall by dangerous conditions of meter boxes.

I have given a great deal of attention to meter box settings because they are more potential hazards to the public safety than other pieces of waterworks equipment. There are other waterworks activities in which safety precautions should be taken to prevent injury to the public.

In laying water mains and services all water utilities cut trenches in the city streets. These trenches should be guarded with a safety horse or barricade which can readily be seen by anyone approaching. They should be well lighted with red lanterns at night. If this trench is in a highway or street with heavy traffic it is wise to employ a watchman to see that the red lights are kept burning. If the job is too small for the employment of a watchman a notice to the police captain of the location of the trench will often bring police aid. We have found this particularly advantageous in learning that barricades have been knocked down by cars, red lights out or stolen.

Another source of public injury accidents is the automotive equipment operated by the water utilities. This class of accidents have been highly publicized. In every magazine or trade journal much

has been written on the proper way to handle an automobile. Safe driving instructions are important points in safety education. All drivers should be well schooled on these points. Safe driving should be second nature to him but in addition he should be taught to recognize defects in his equipment. He should take especial care to see that his steering gear is in proper condition, that emergency and service brakes are right. It is important that the front tires be in good condition and not liable to blow out. The front lights and tail lights must be in good order at all times. A general check-up of all the automotive equipment should be made at least once a month, and any defective condition corrected by competent mechanics. These are the features of safety education to prevent accidents. It is necessary for the water utility to school its drivers also in what to do after the accident happens.

The first rule all drivers of water utility cars should observe is never leave the scene of the accident until he has given his name, address, company name and his license number, and at the same time get this same information from the driver of the other car, if it is an auto collision accident. It is also very important for him to get the name and address of all occupants of the other car. If possible the names of witnesses should be taken and the relative positions of the cars at the point of contact is useful in determining who was at fault. The driver should give notice to the main office of his utility at the first opportunity but should not give such notice before securing the necessary information.

During the year 1936 the City Water Company of Chattanooga operated eight service trucks a total of 124,000 miles without an accident of any kind. It has been my personal experience that safety education together with organized safety efforts will reduce accidents.

There is another phase of public accidents which I have not touched on, in which I think waterworks operators should be interested.

In 1930, the second year of the depression, the City Water Company of Chattanooga had numerous suits and claims for injuries brought by people from every section of the city. The depression no doubt was responsible for most of these suits. People were out of work with nothing to do but discuss their plight. These discussions often took place around the home fires. The need for money being urgent I am sure any suggestion as to a plan for obtaining money was readily received. Some of these plans evidently concerned lawsuits as one of the means of obtaining money. Organized

gangs began bringing fraudulent lawsuits. These suits are hard to defeat because the gangs all have legal advice and know just what evidence to present.

During the year all the other public utilities of the city were being swamped with lawsuits. We soon took notice of the fact that a plaintiff suing the Water Company was a witness also for a plaintiff suing the Power Company. The plaintiff suing the Power Company would be a witness for another plaintiff suing the Telephone Company. We also learned that these people all lived in the same neighborhood or were related. They all had the same group of lawyers but changed doctors. The men were the leaders of these groups but they usually had their wives named as plaintiffs, as women were more likely to recover. The nature of their injuries were always about the same, wrenched backs and abdominal injuries. The wrenched back is the easiest injury to fake. The doctor making an examination for a back injury can only press on the back and take note of the place on the back where the supposedly injured person claims the pressure causes pain. The symptoms are purely subjective. The usual examination will show nothing except a bruise or slight swelling. Such a bruise can be inflicted on the back with a light blow from which there will be little or no pain or suffering. In consideration of a fast recovery in court a slight injury was nothing. Immediately after the trial, the walking cane or crutch is discarded.

When these cases began developing the lawyers and claim adjustors of the public utilities formed an association in which the different claims and claimants were discussed. The legal files and records of all these companies were opened to all the members of the association. It became a sort of clearing house for all lawsuits. When a suit was brought the plaintiff was immediately checked up in the files of the other members and his part in other suits brought out in the court trial. The trial judges on hearing this evidence were very lax in permitting cross examining questions and overruled many objections which otherwise would have been allowed. This association did not proceed to the point of prosecution of the plaintiffs of fraudulent suits, but did succeed in breaking up several gangs in the lawsuit rackets. In this age where gangs of all kinds are wont to thrive at the expense of legitimate business, I think it would be well for all water utilities to take notice also of this class of public accidents.

Therefore, as we strive at all times to keep our water supply in a safe condition, we must do likewise in our physical properties.

ABSTRACTS OF WATER WORKS LITERATURE

Key: JOURNAL of the American Water Works Association, **29**: 10 (1937). The figure 29 refers to the volume, 10 to the page of the JOURNAL and (1937) to the year of issue. If volumes of a publication are not paged consecutively but by issues, the figures **29**: 1; 10 (1937) indicate—volume 29, number 1, page 10 and 1937 as the year of issue.

TASTE AND ODOR CONTROL

Odor Measurement. HERMANN BACH. Ges. Ing. **60**: 222 (1937). Recent American papers relating to procedures and apparatus to test odor in water and sewage are discussed. Possible errors with air dilution methods due to effect of oxygen on readily oxydizable matter such as hydrogen sulphide, etc. especially with high dilutions are to be considered.—*Manz.*

Discussion of the Taste and Odor Problem. L. H. ENSLOW. 13th Ann. Rept. Ohio Conf. Water Purification, 89 (1937). The action of saprophytic bacteria on slime deposits during warm-water conditions causes O depletion, tastes and odors and red water in outlying sections of distribution systems. These difficulties may be controlled by maintaining residual Cl throughout the system by NH_3-Cl treatment. The residual Cl content must be increased gradually, however, in order to avoid sudden sloughing off of the slime. A prior flushing of the mains is desirable.—*R. E. Thompson.*

Taste and Odor Trouble at Barberton and its Remedy. F. L. ROLLINS AND A. D. CLAGGETTE. 13th Ann. Rept. Ohio Conf. Water Purification, 88 (1937). The water supply of Barberton is obtained from a 670-million gal. impounding reservoir, more than half of the drainage area being swamp and marsh land. Taste and odor troubles, due to microscopic organisms, are prevalent and activated C and NH_3-Cl treatments are only partially effective. In 1933, excess lime treatment (maintaining a caustic alky. of 15 p.p.m.) and recarbonation was adopted. This treatment, in addn. to removing all objectionable tastes and odors, reduces the hardness from 140 to 80 p.p.m. and effects a saving of about $1000 per year in operating costs.—*R. E. Thompson.*

Solving a Taste Problem at Salt Lake City. AMBER G. KNIGHT. W. Cons. News, **11**: 189 (1936). Tree leaves affected the taste of the water. The trouble was overcome by increasing ratio of chlorine to ammonia employed.—*R. E. Thompson.*

LABORATORY METHODS—BACTERIOLOGICAL

Acid Production by the Escherichia-aerobacter Group of Bacteria as Indicated by Dissolved Metallic Iron. A. V. Syrocki, James E. Fuller and Ralph L. France. J. Bact., 33: 185 (1937). "Bacteria of the *Escherichia-Aerobacter* group were cultivated in a peptone-glucose medium containing iron filings. All organisms produced sufficient acid in 24 hours to dissolve some of the iron. Potassium ferricyanide solution was employed as an indicator of dissolved iron. When 0.3% buffer (K_2HPO_4) was added to the medium, *Escherichia coli* still was able to produce sufficient acid to dissolve the iron, but the acid produced by *Aerobacter aerogenes* was neutralized by the buffer. Iron was dissolved sufficient for detection with ferricyanide. In the medium without iron the cultures attained pH values lower than in the medium with iron. When employed with pure cultures the procedure made possible a satisfactory differentiation of *Escherichia coli* from *Aerobacter aerogenes* and from intermediates of the group. Differentiation of other members of the group from each other was not accomplished. The method is suggested as a means of studying the acid production of the organisms from various carbohydrates." —*Ralph E. Noble.*

The Bacteriostatic Action of Brilliant Green in Solid Media on Members of the Colon-aerogenes Group and Their Intermediates. Arnold E. Hook and E. R. Hitchner. J. Bact. 33: 88 (1937). A 1:1000 aqueous solution of brilliant green was added to nutrient agar (Difco), pH 7.0, in sufficient amounts to give the following concentrations in thousands: 1:25, 1:33, 1:50, 1:100, 1:200, 1:330, 1:400, 1:660, and 1:833. Duplicate plates of each concentration were inoculated by streaking with a standard 2 mm. loopful of a 1:10, 1:100, and 1:1000 dilution of a 24-hour old broth culture of the various cultures. The inhibitory effect was observed after varying periods of incubation at 37°C. All cultures exhibited a greater dye tolerance when larger inocula were used. *Aerobacter* strains grew at a much higher dye concentration than the *Escherichia* strains. Within the genus the various cultures of both *Escherichia* and *Aerobacter* exhibited marked differences in dye tolerance, being more marked in representatives of the *Escherichia* group. Upon prolonged incubation many cultures produced visible growth at a dye concentration inhibitory during a shorter incubation period. A preliminary study with a few representative strains of *Escherichia coli* and *Aerobacter aerogenes* showed that when a 1:10 dilution of a 24-hour old culture of the various strains was streaked on nutrient agar containing a 1:200,000 concentration of the dye, all *Escherichia* cultures showed no visible growth after 48 hours, while all *Aerobacter* strains grew rapidly. Further tests with 103 cultures, comprising 19 *Aerobacter* strains, 61 *Escherichia* strains, and 23 intermediates, differentiated by the M.R.V.P., indol, citrate and cellobiose tests, confirmed the results from the preliminary study with *Escherichia* and *Aerobacter* strains. The authors suggest the above procedure as a further means of differentiating the latter.—*Ralph E. Noble.*

Streptococcus Fecalis. J. M. Sherman, J. C. Mauer and Pauline Stark. J. Bact. 33: 275 (1937). A study was made of 434 cultures of *Streptococcus*

fecalis with the application of a more extensive test series than has been used heretofore. Especial attention was paid to certain basic tests of primary differential value which are not in general use for streptococci study. The fermentation tests are diverse within this species and are regarded as of minor value in its description. On the basis of the more fundamental tests, the species is made up of a very homogeneous group of organisms, and no justification was found for its subdivision on the basis of the fermentation tests.—*Ralph E. Noble.*

Decomposition of Carbohydrates and Alcohols with Production of Gas at 46°C. by Members of the Genus Escherichia. A. A. HAJNA. J. Bact. 33: 339 (1937). The action of 129 strains of the genus *Escherichia* on 7 monosaccharides, 4 disaccharides, and 4 alcohols at 37° and 46°C has been studied. 8 different basic media were used in order to observe the effect of buffers, peptone, meat infusion, and meat extract on gas production. Buffers enhanced gas production at both temperatures. In a well-buffered basic medium, all sugars and alcohols tested, except dulcitol and adonitol, which were never fermented with gas at 46°C., were readily decomposed at both temperatures. In an adequately buffered medium, all the strains used remained viable after 72 hours. Gas production is likewise influenced greatly by the type of protein. Meat extract restrained gas production. Less gas was formed in meat infusion freed of muscle sugar.—*Ralph E. Noble.*

Relations between Plate Counts and Direct Microscopic Counts of Escherichia Coli during the Logarithmic Growth Period. MARSHALL W. JENNISON. J. Bact. 33: 461 (1937). "For *Escherichia coli*, in broth culture at different temperatures from 22° to 37°C., the following conclusions may be drawn relative to its behavior during the logarithmic growth period: Even in young cultures there is considerable clumping, the group counts having averaged 70% of total counts, after shaking. Discrepancies between plate and total counts can be wholly explained, within the limits of experimental error, by clumping of cells, other conditions being optimum. Plate count, due to varying amounts of clumping at different times, does not bear a constant relation to the total (individual) cell count throughout the logarithmic period. When there is clumping, therefore, a plate count *may* not be a reliable measure of the number of cells present relative to the total. If groups of bacteria can be completely broken up, the plate count and total counts will be practically identical during the period of maximum rate of reproduction. Different temperatures of growth seem to have no significant effect upon viability of these bacteria in culture. Results indicate practically 100% viability *in culture* for this organism. There may be a tendency for some cells to die during the plating-out process."—*Ralph E. Noble.*

Growth Inhibition of Escherichia coli. K. M. WHEELER AND C. A. STUART. J. Bact. 33: 525 (1937). Using twin tubes, similar to those described by Asheshov, a growth-inhibitory action as demonstrated for *Escherichia coli*. Inhibition could not be attributed to a lack of nutrient materials in beef extract and peptone. The inhibitory substance was thermostable and dialyzable.

Inhibition was nonspecific since *Eberthella typhosa* and *Staphylococcus aureus* showed decreased growth similar to that of *Escherichia coli*.—*Ralph E. Noble.*

CORROSION AND CORROSION CONTROL

Improvement in Electrical Pipe Protection Equipment. W. R. SCHNEIDER. Gas, 12: 6; 22 (1936). Cathodic protection of pipe lines has been facilitated by use of new rectifier equipment for supplying up to 50 amperes direct current at voltages up to 19, variable in 1-volt steps. Weight and cost have been reduced and equipment has been simplified. Direct-current potential required for pipe protection is found by adding (1) pipe-to-soil potential at eliminator station, with optimum compensating current passing through eliminator or test battery; (2) drop of potential in various leads and connections; (3) ground electrode and pipe polarization potentials (approximately 1 volt); (4) back potential of 1.0 volt if a carbon ground is used; and (5) drop of potential at ground electrode (from chart). Horizontal ground electrodes are preferably laid in straight line, at depth of 5 feet or more, in soil moist throughout year. Electrode should be spaced at least 50 diameters from pipe line protected and connections made by brazing or welding a 250,000 circular mill, rubber-covered copper cable to 2 points on each length of pipe (preferably cast iron).—*R. E. Thompson.*

Dissimilar Metal Corrosion in Soils. F. A. HOUGH AND A. B. ALLYNE. Gas, 12: 5; 18 (1936). Copper pipe brazed to steel pipe in underground distribution system was investigated to determine possibility of bimetallic corrosion due to these dissimilar metals. Polarization of copper-steel cells was found much more effective in reducing current flow in soils than in salt water in motion. Residual potential density between polarized carbon and steel was much greater in some soils than others, varying from 0.005 to 0.20 volt. In former, soil corrosion would be negligible, and of uncertain importance in latter. Relative area of copper and steel electrodes is very important factor in determining rate of corrosion of steel. It was found that as great or even greater potential differences than observed with copper-steel cells could be obtained by oxygen concentration cells, while resistance of former was from 5 to 7 times probable resistance of latter, when two metal surfaces are separated at least 3 feet as they would be in distribution system. These facts make it seem improbable that dissimilar metal corrosion would be determining factor in fixing life of steel pipe used with copper pipe, but this conclusion must be confirmed by long-time tests.—*R. E. Thompson.*

Bituminous Coatings as Rust Protection for Tubes. K. ADLOFF. Bitumen, 5: 107 (1936). Cast iron, wrought iron and molybdenum steel tubes were coated with: (1) ordinary paint with linseed-oil base, (2) paint with a chlorinated rubber base, (3) bituminous paint, (4) ground coat of red lead covered with cold liquid bitumen, and (5) double application of cold liquid bitumen-filler mixture. Pipes were buried in location free from stray currents and under like conditions. They were tested by being made anodes in system with zinc cathode and 2-volt current. Coating with bituminous filler gave best results; red lead-bituminous paint combination also gave good results; other

3 coatings failed early. Current permeability of coatings was tested by an electromagnetic device.—*R. E. Thompson.*

Vacuum Deaeration Combats Cold-Water Corrosion. SHEPPARD T. POWELL AND HOMER S. BURNS. Chem. Met. Eng., 43: 180 (1936). Pipe line designed to carry approximately 4 million gallons per day of raw Mississippi River water 9 miles to point of use suffered rapid loss of capacity due to oxygen corrosion. Economic solution of this corrosion problem was obtained by combination of mechanical and chemical deaeration. Passage through slat-packed vacuum tower maintained at 28.5 inches of mercury removed 95 percent of oxygen and final clean-up was accomplished by addition of sodium sulfite.—*R. E. Thompson.*

Corrosion and Friction in Mine Pumping Systems. JOHN SMELLIE. Colliery Eng., 13: 230 (1936). Proper choice of material and bituminous linings are usual means of preventing corrosion. Deposits are usually impurities in solution and consist of calcium carbonate, ferric hydroxide, other inorganic substances, slimes and organic growths. Extreme irregularity of deposits is due to original nature of pipe surface. Calculations of pipe friction, economical size of pipe and tables of results of pipe line testing are given together with photographs of corroded parts and those containing carbonate deposits.—*R. E. Thompson.*

Corrosion in Water Works. G. WIEGAND. Gas- u. Wasserfach, 79: 198 (1936). Ground water containing hydrogen sulfide, even in small amounts, has deteriorating effect on well filter screens of copper or brass, and also on zinc pipe coatings. Ceramic ware, hard rubber or even glass has been used in severe cases. Aerator equipment may also be attacked by hydrogen sulfide, and in some cases aluminum covered with bitumen may be substituted for brass. A corrosive water dissolved zinc out of brass tubes in filter bed; phosphor bronze gave satisfactory service. Corrosion of wrought-iron supports for copper screen in filter bed was attributed to electrolytic action: Eternit supports were substituted. Decomposition of rubbish, etc., may cause hydrogen sulfide formation and (external) pipe corrosion. Dead-end mains may be attacked by waters low in iron, and iron again deposited, tending to reduce flow through such mains.—*R. E. Thompson.*

Report on Protective Coatings for Underground Pipes. A. B. DENSHAM AND F. C. SMITH. Inst. Gas. Engrs. Publ. no. 115 (1935). Accelerated methods for testing efficacy of various protective coatings are described. Steel and wrought-iron service pipes corrode to much the same extent when exposed to electrolytic corrosion; both must be protected by coating. Pitch troughing, bitumen asbestos sheathing, bitumen felt coating, bitumen hessian coating, thin adhesive bandage consisting mainly of hydrocarbon material (proprietary) and a bituminous paint (proprietary) covered with insulation tape all gave good protection against electrolytic corrosion. Pitch troughing in metal or cardboard molds is adequate method of protecting joints. Galvanizing, cotton fabric filled with grease (proprietary), cement troughing and a bitumi-

nous paint (proprietary) applied over red lead gave inadequate protection. Order of merit of coatings investigated, judged from electrical resistance, is roughly same as order judged from amount of corrosion by impressed current after exposure for 2.5 years. Probably the electrical resistance test gives reliable measure of protective power of a coating. Sixty references.—*R. E. Thompson.*

Soil Corrosion Studies, 1934. Rates of Loss of Weight and Pitting of Ferrous Specimens. K. H. LOGAN. J. Research-Natl. Bur. Standards, 16: 431 (1936). In general, results of examination of specimens removed in 1934 confirm earlier conclusions. Average maximum penetrations for wrought-iron, Bessemer, and open-hearth specimens do not differ by more than few percent. Specimens of open-hearth iron and an open-hearth steel containing 0.2 percent copper appeared to pit slightly more deeply than other wrought specimens. Addition of copper alone to steel did not increase its resistance to most soils. In some soils, cast iron corroded somewhat more rapidly than steel. Addition of chromium to steel reduced loss of weight by corrosion and number of pits, but even large percentage of chromium did not prevent serious pitting, especially in soils containing chlorides. Addition of nickel, with or without chromium, tended to reduce depth of pits. Soils differ so greatly in corrosiveness that average rates of corrosion or average life of pipe have little practical value. No material has been found which will withstand corrosion under all soil conditions, but certain materials seem to be especially suited or unsuited to certain types of soil.—*R. E. Thompson.*

Aggressive Waters and Their Treatment. KARL SCHILLING. Gas- u. Wasserfach, 79: 542 (1936). Economic limits for bound and free carbon dioxide in deacidification with marble are shown graphically. Lime treatment is also discussed. Calculations regarding aggressivity of water (toward lime) do not agree well with experimental results. Corrosive nature of waters containing carbon dioxide is discussed; these waters are much more dangerous in presence of oxygen, as more rapid and localized corrosion may result. Rate of attack increases with decreasing pH, increasing oxygen, and temperature. Velocity of flow is also an important factor.—*R. E. Thompson.*

Electrolytic Measurements of the Corrosiveness of Soils. I. A. DENISON. J. Research, Natl. Bur. Standards, 17: 363 (1936). Electrolytic behaviour of steel in contact with 47 soils of known corrosiveness was studied by means of cell in which both electrodes were steel and the electrolyte was moist soil. By aerating cathode more than anode and closing external circuit, cell was enabled to develop its own electromotive force. Quantity of electricity developed by cell over 2-week period is approximately proportional to loss of weight of anode and to corrosion losses in field tests. The corrosion test may be accelerated by use of external electromotive force. From relation between current density and voltage impressed across cell, corrected for IR drop, relative corrosiveness of soil can be predicted. Time curves of voltage, current and resistance of corrosion cells that operated only with electromotive force associated with corrosion were influenced by physical and chemical properties of soils.

Chief factors that induce corrosion in soils are high concentrations of soluble salts, especially those of alkali metals, and high acidity. Both factors tend to increase solubility of hydroxides of iron and to prevent formation of protective layers of corrosion products. Corrosion is relatively slight, except under conditions of poor drainage, in soils in which content of bicarbonate in water extract of soil is equivalent to sum of calcium and magnesium ions. Well-aerated soils, in which hydroxides of iron are precipitated in immediate contact with corroding surface, are usually non-corrosive. Results of laboratory tests on soil were correlated with loss in weight and depth of deepest pit on 1 square foot of ferrous materials exposed to that soil for 12 years. Results of tests may be applied practically in predicting corrosiveness of soils toward iron and steel; however, they cannot be applied to prediction of leaks or to the estimation of useful life of section of pipe line until relations connecting depth of pitting with exposed area and time can be established. Many data, figures and 15 references are given.—*R. E. Thompson.*

Chlorinated Rubber as Protective Coating Against Corrosion. G. SCHULTZE. Korrosion u. Metallschutz, 12: 249 (1936). Various types of primers and protective coatings containing chlorinated rubber are discussed. Photographs of steel plates painted with this type of coating and exposed for 4 years to acid and alkaline soils containing 80 per cent moisture are shown. Very satisfactory protection was obtained.—*R. E. Thompson.*

Heat Flow as a Cause of Corrosion. HANS KRENN. Arch. Wärmewirt., 17: 115 (1936). Two identical pieces of steel kept at different temperatures in weak electrolyte showed potential difference of over a millivolt. Various specific cases of corrosion in boilers, superheaters and turbines are attributed to electrolysis created by currents so generated. In one case the corrosion was stopped by imposing suitable external electromotive force.—*R. E. Thompson.*

Comparative Attack of Hard and Soft Lead Pipe by Water. ERICH NAUMANN. Gas- u. Wasserfach, 79: 214 (1936). For given period of contact, amount of lead removed by given hard water was essentially same for soft lead and hard lead (containing antimony) pipe. In both cases amount of lead removed increased sharply as pH of water dropped below about 7.—*R. E. Thompson.*

Resistance of Cement Pipes to Acids. E. SUENSON. Ingeniørvidenskab. Skrifter, 1935B, No. 15. Data are given on destruction of pipes in Danish soil. In cases of attack, outer surface was affected when pipes made from lean mixes were below subsurface water level, in aquiferous strata. No attack was found in clay soils, or with wet-molded, water-cured specimens. Data are given on corrosion of hardened cements by various waters. Pipes could be made which resisted action of carbonic acid solution: conditions are described. Leanest mix for resistance was cement 1, sand 2. Moler (kieselguhr) cement pipes were less durable than those made with portland cement. Lean mixes impregnated with tar or asphalt were resistant, although blistering

occurred and pipes were not completely watertight. Resistances of mortar test bars to lactic, carbonic and hydrochloric acids were determined by transverse- and crushing-strength tests after acid attack. For same cement: sand ratios, resistance of Moler cement was greater than that of rapid-hardening or normal portland cements. Reduction in crushing strength caused by attack was greater than that in transverse strength. Impregnation with thick tar, where possible, improved resistance; thin tar had little effect. Sodium silicate and soap reduced permeability, but did not increase acid resistance, and soap reduced mortar strength. Series of experiments on sources of error in permeability tests are described.—*R. E. Thompson.*

Corrosiveness of Aqueduct Water Reduced by Gas Drainage. ANON. Eng. News-Rec., 117: 790 (1936). Analyses of water at various points in 250-mile aqueduct which conveys Owens Valley water to Los Angeles indicated that corrosiveness of water increased suddenly in Soda Hill tunnel near Little Lake due to seepage of large amounts of carbon dioxide into tunnel. From single source, concentrated in about 7000 feet of tunnel, carbon dioxide content increased from negligible quantity to 4.2 p.p.m. When tunnel was unwatered for inspection, it was found that gas in rock formation traversed is under sufficient pressure to cause hissing sound as it enters tunnel through cracks and small openings in concrete lining. Construction was recently begun on remedial plan which involves installation of drainage trench beneath floor of tunnel. Strip of concrete 30 inches wide is being broken out from mid portion of invert and 15 x 15-inch trench excavated in rock beneath. When full length of trench has been excavated and thoroughly cleaned, it will be bridged with corrugated iron as bottom form on which to pour concrete replacing strip removed. Fortunately, Soda Hill tunnel is located along hillside in which there are ravines at frequent intervals to afford convenient locations for necessary adits, 8 in all, totaling about 2,000 feet in length. Each adit will terminate in full-size opening cut in side wall of tunnel. Six of openings will be sealed again with concrete (except for trench) after trenching has been completed and other 2 will be closed with iron door to facilitate later access. Expectation is that gas will find its way around outside of tunnel lining into trench, flow to nearest adit and continue therein on down-grade to open air. All cracks and breaks in tunnel lining are being repaired as work progresses. If plan under way does not provide sufficient gas drainage, next step will be to make more direct path to trench by cutting rings entirely around tunnel at intervals by excavating circumferential cuts through lining into rock and then replacing lining.—*R. E. Thompson.*

Resistant Metals. C. R. VINCENT. Ind. Eng. Chem., 29: 389 (1937). Increase in use of alloys is due largely to resistance to corrosion, scaling, elevated temperatures, etc. Though first cost may be high, economy may be realized in long run. Improvement in art of welding has done much to spread use of alloys in industry. Use in welded tanks, tank liners, and other appurtenances of chemical industry, and methods of using alloys are discussed.—*Selma Gottlieb.*

New Processes for the Deacidification of Water. E. NAUMANN. Gas- u. Wasserfach, 79: 161 (1936). Goal of deacidification processes is to permit formation of protective layer of calcium carbonate on interior of pipes, thus preventing corrosion. *Aeration.* This process depends on mechanical removal of carbon dioxide; water is also saturated with oxygen. Process is limited to waters harder than 7° (1 German degree = 10 p.p.m. CaO) as it is not ordinarily possible to reduce free carbon dioxide to less than 5–7 p.p.m. Wide variety of contact apparatus can be used but best results are secured by atomization through 2 "Amsterdam" nozzles at right angles, so that sprays impinge on each other. Advantages are automatic operation, absence of control apparatus, and facilitation of iron and manganese removal. A disadvantage is necessity of extra pumping step, as closed aerators cannot be used. *Filtration through marble.* This depends on reaction of carbon dioxide with calcium carbonate to form calcium bicarbonate, causing water to become harder. Filter must be of generous size. Very soft water must be completely deacidified; free carbon dioxide is not so dangerous with harder waters—such waters are deacidified at lower rate. Process is limited to soft waters where sum of bound and free carbon dioxide is between 20 and 60 p.p.m. and hardness from 2.5 to maximum of 7.5°. Only traces of iron, manganese, color or turbidity should be present as their deposition reduces efficiency of filters. Filters may be either open or closed but should be of upward flow type. Advantages are minimum of supervision required and insensitivity to large variations in carbon dioxide content. *Lime treatment.* Addition of lime water assists in forming supersaturated calcium carbonate solutions on pipe walls even with soft waters and resulting hardness is only half that with marble treatment. Amount added must be measured rather accurately and exact degree of deacidification can be controlled. More supervision is required than with marble. Excess may cause taste; this danger is even more prevalent with other alkalies which may be used. *Magno process.* This method has been used with excellent results for slightly over 2 years. Process uses granular dolomite which has been calcined to such extent as to convert part of magnesium carbonate to magnesium hydroxide without affecting the calcium carbonate, thus greatly changing its properties. First water passing through Magno filter is quite alkaline (pH 9–10) but in few days alkalinity drops to point where only slight color is imparted to phenolphthalein. Open or closed filters may be used and waters of hardness up to at least 8° may be deacidified irrespective of original carbon dioxide content. Separation of iron, manganese and organic substances does not greatly affect process. Fresh material must be added to filter occasionally. Upward flow units are employed. Process is automatic and requires little supervision. Cost data are given for each of processes dealt with.—*R. E. Thompson.*

WATER SOFTENING AND IRON REMOVAL

Treatment of Drinking Water by Means of the Berkefeld "Rapid" Iron-Removing Equipment. H. KLIEWE. Gesundh.-Ing., 59: 285 (1936). Closed units of commercial type are described in which basic filtering medium imparts alkaline reaction to water, precipitating the iron, and simultaneously filters

out the precipitated hydroxide. Effectiveness of units tested is shown in reported results.—*R. E. Thompson.*

A Simple Method of Iron Removal and Two New Methods in Purifying Water. ANON. Textile Mfr., 62: 154 (1936). Some synthetic resins from certain phenols and tannins are as effective as best usual water softening materials in removing calcium and magnesium from hard water. Other resins from aromatic bases remove anions. Treatment of certain tap water first with tannin resin and then with aniline resin reduced dissolved solids from 330 to 10 p.p.m. Same process repeated 2 or 3 times removes most of salt from sea water. Iron removal is effected by filter containing patented material whose composition is not disclosed: for satisfactory results, sulfides must be absent, dissolved oxygen must be at least 15 per cent of iron and manganese content and pH must be at least 6.5.—*R. E. Thompson.*

Softening of Water with Trisodium Phosphate. P. SCHLÄPFER. Schweiz. Arch. 1: 126 (1935). In presence of sodium bicarbonate, complete softening cannot be obtained even with trisodium phosphate; to obtain practically zero hardness it is necessary to decompose sodium bicarbonate by boiling or by adding sodium hydroxide. Water containing large quantities of magnesium salts cannot be completely softened in cold by lime process, as magnesium carbonate is relatively soluble and magnesium hydroxide cannot be eliminated in the cold; they are precipitated, however, at higher temperatures. To detect phosphate ions in boiler water, to 1 cc. water add 10 cc. molybdic reagent (to 1 liter of concentrated nitric acid add 150 cc. cold saturated ammonium molybdate solution and 25 grams ammonium nitrate, stir vigorously, let stand and decant from precipitate) previously heated to 70° and note formation of yellow coloration or precipitate; phosphate content can be estimated approximately from speed and intensity with which these phenomena appear.—*R. E. Thompson.*

The Softening of Industrial Waters by Trisodium Phosphate. LOUIS GERMAIN. Rev. 45: 7 (1936). Trisodium phosphate can give, even in cold, water nearly as soft as permutite-treated water at appreciably lower cost. Soluble calcium and magnesium salts are converted into basic phosphates of very low solubility which contain more than 3 CaO or 3 MgO per P_2O_5. Precipitation of lime is much more complete than that of magnesia. Trisodium phosphate should not be used as sole softening agent, and it is preferable to use it on water that has been partially softened by lime-soda process. It is even more economical to use disodium phosphate and sodium hydroxide, but preliminary lime-soda treatment must be modified accordingly. Phosphate softening is more rapid and complete at elevated temperatures, but heating is warranted only if softened water is to be used immediately and at temperature at least as high as that of treatment. Trisodium phosphate softening dispenses with special treatment for removal of iron and manganese, as their tribasic phosphates are completely insoluble.—*R. E. Thompson.*

The Elimination of Salts from Water. JEAN BILLITER. Trans. Electrochem. Soc., 70: (1936). Natural water can be readily and efficiently desalted

by electrolysis by use of 3-compartment cell. It is shown that belief that purification in this cell is due primarily to electroosmosis is erroneous. Primary step in process is that of electrodialysis. Extensive large-scale tests indicate average current efficiency of 18 per cent, which corresponds very closely to theory. Over 80 per cent of current is consumed in recombination of hydrogen and hydroxyl ions formed in outer compartments and recombining in middle compartment. Waters containing wide diversity of salts, such as sulfates, chlorides, carbonates and bicarbonates, may be treated in author's Hydor cell, even waters difficult or impossible to treat by older methods.—*R. E. Thompson.*

MAINTENANCE AND OPERATION

Maintenance of Water Systems During the Winter Season. W. E. MACDONALD. Eng. Cont. Rec., 50: 1085 (1936). Experiences and practice in Ottawa, Ontario, are discussed. When making repairs or extensions to distribution system in severe weather, insulation of exposed mains and services by wrapping with hair felt and encasing in mineral wool is effective method of avoiding freezing. Immediately after closing down section involved, services should be emptied by backblowing with compressed air. Freezing of sprinkler system services is constant source of difficulty. Tapping domestic or commercial services to these connections immediately inside property wall would relieve this situation. In regard to freezing of mains, author has considered, in extreme cases, heating by electricity, using spirally wound copper wire on outside of pipe. If power were continuously applied during extreme cold weather, it appears that application of 1.5 watts for 6-inch pipe and 2 watts for 8-inch would suffice in Ottawa, where mains are installed with minimum cover of 7 feet. It has been estimated that it would be necessary to tap main every 500 feet, using 22 volts. For 6-inch main, 1000 feet of No. 8 weatherproof wire would be required and cost for wire only (50 pounds copper: $13.50) would be 2.7¢ per foot of pipe. In 1933–4, ice formed in settling basins to depth as great as 7 inches, necessitating frequent emptying for removal. Ordinarily, frost rarely penetrates more than 5 feet below ground surface in Ottawa but in 1933–4 penetrations of at least 8 feet were observed. In one case, 6-inch main covered with 7 foot, 3 inches of earth and asphalt topping was found to be frozen solidly for distance of more than 60 linear feet. This condition only occurred where snow had been removed from streets. On one street, frost had penetrated over 6 feet where snow had been ploughed off, but near street line, where there was cover of 4 feet of snow, frost penetration was only 18 inches. Services are thawed with self-contained apparatus designed by writer which has saved considerable amount of money for department. Fleet of trucks on which are mounted steam boilers are maintained for thawing hydrants and these are used for services also under certain conditions. These trucks respond to all fire alarms during severe weather. When services are frozen on private property, charge of $3.00 per half hour is made for thawing.—*R. E. Thompson.*

Detroit's Accounting System for Water-Works Customers. HAL. F. SMITH. Am. City. 52: 4; 57 (1937). The Detroit, Michigan Department of Water Supply with 274,000 customers accounts, almost all of which are metered, has

an accounting system which does its job accurately, thoroughly and economically. Important features of the scheme are the master control which includes 40 controlling accounts (1 for each of 36 districts and 4 for other divisions) so arranged in the ledger as to give a daily summary of all entries made to customers accounts and 1756 sub-controlling accounts (1 for each reading route) on which are entered the last balance and the total daily debits and credits. These controls have simplified the securing of trial balances.—*Arthur P. Miller.*

Controlling the Plumber. NATHAN N. WOLPERT. W. W. Eng., 90: 140 (1937). Reports results of survey to determine what practice is in various cities with respect to use of licensed plumbers laying service lines from main to curb. No definite trend among cities reporting. Many departments have resisted attempts by plumbers to run service lines either from main or curb box. Some departments have plumbers set meters. Number of sample plumbers permit blanks are given.—*Lewis V. Carpenter.*

Cast Iron Pipe with Flexible Joints Used for Stream Crossing. ALEXANDER ALLISON, JR. Eng. News-Rec., 117: 853 (1936). Description of laying of 12-inch water main under inner harbor navigation canal at New Orleans, which is 300 feet wide at top and 175 feet at bottom, with depth of 30 feet below mean low lake level. It was required that top of pipe should be at least 10 feet below bottom of canal for full width. Special type of flexible joint used, which was manufactured as integral part of 16-foot pipe lengths, is described and illustrated. Joint permits angular deflection of 15 degrees from straight line in any direction.—*R. E. Thompson.*

Cleaning Pressure Mains at the Breslau Municipal Water Works and Its Influence on the Raw Water Composition and Bacterial Count. W. AUSTEN. Gas- u. Wasserfach, 79: 617 (1936). Deposits on pipe walls served as catalysts to cause iron compounds in raw water to be precipitated and suspended in colloidal form when water was aerated so that they escaped later precipitation with lime. Cleaning the mains eliminated this difficulty. No change in bacterial count was noted.—*R. E. Thompson.*

Pipe Thawing by Electrical Methods. ROSS L. DOBBIN. Eng. Cont. Rec., 50: 13 (1937). Principal methods of electrical thawing utilize (1) standard distribution transformers, (2) special low voltage transformers and (3) engine driven generator sets. These methods are discussed in regard to costs, etc. In Peterborough, Ontario, standard distribution transformers are used with primaries connected in series and secondaries in parallel. In 1934, average cost per service was $2.39. If service is frozen on consumer's property, charge of $4 is made, otherwise cost is absorbed by department. Recent survey of Canadian practice showed that charge to consumer varies between $2 and $10, average being about $4. All grounds of any kind should be removed and pipe disconnected as near as possible to cellar wall, cutting pipe if necessary. Great care is required in thawing interior piping electrically. In Peterborough, such work will not be undertaken by water department.—*R. E. Thompson.*

Thawing Service Pipes—A Review. FRANK C. AMSBARY. W. Wks. and Sew., 84: 45 (1937). Thorough discussion of electrical thawing, together with results of questionnaire summarizing other methods of thawing. Effect of type of pipe material, current used, time required, method of payment, fire hazards, and thawing mains are discussed. Numerous warnings against various hazards, and suggestions on procedures, are given.—*H. E. Hudson, Jr.*

Practical Electricity in the Plant. MARSDEN C. SMITH. I. W. Wks. and Sew., 83: 388 (1936). Electrical units, direct and alternating current, and transformers with their effect on choice of equipment, are discussed. II. Ibid., 83: 480 (1936). Significance and definitions of the Watt, power-factor, kilowatt-hour, and phase, are given. Grounding practice and the three-phase standard for heavy duty are set forth. III. Ibid., 84: 59 (1937). Continuation of general resumé of electrical knowledge valuable to water works man. This paper discusses fuses, circuit breakers, relays, and grounding.—*H. E. Hudson, Jr.*

Birmingham, Ala., Secures an Industrial Water Supply. A. CLINTON DECKER W. Wks. and Sew., 83: 403 (1936). Birmingham has a public water supply adequate for domestic use, but needs added water for industries. This is being provided by development of separate 60 M.G.D. surface water supply which will consist of 21,000 M.G. impounding reservoir, 30 mile supply main, pumping station, chlorinating and liming equipment, and distribution system using both steel and cast iron pipe. Work is being done partly by W. P. A. and partly by P. W. A. contracts. Water is to be superchlorinated as public health measure.—*H. E. Hudson, Jr.*

Free Water—God's Gift. JAS. MCCLURE WARDLE. W. Wks. and Sew., 83: 409 (1936). Hudson, N. Y., population—13,000, has gravity surface supply, paid for out of general taxes. $10,000 is available annually for operating costs. A few large accounts are metered, all others pay nothing. Water Board has been unsuccessful in attempts to put financing on rational basis. Skimping necessitated by lack of funds is wittily related.—*H. E. Hudson, Jr.*

Ground Water

London water supply augmented by new underground system. ROSS NEBOLSINE. Eng. News-Rec., 117: 576 (1936). A patented process for projecting radial, horizontal, collecting screen pipes from a well and building up a gravel pack around them is described. A well of this type was constructed in London, Eng., during the 1934 drought. This installation consists of a shaft, 12.5 ft. in diameter, sunk to a depth of 20 ft. in alluvial sand and gravel overlying a thick bed of clay, and 9 radiating screen pipes, 7 ft. in diameter, extending horizontally up to 165 ft. into the water-bearing strata 1 ft. above the clay. Only 4 of the longest collector pipes were used, supplying an av. of 1.8 million gallons per day during the drought season when the undisturbed water table was only 5 ft. above the screens. Normally, with the water table 11 ft. above the pipes, this capacity is more than doubled. The radial well may also be used for recharging underground storage.—*R. E. Thompson.*

New Well Regulation in New Haven. Conn. Health Bulletin. 59: 9; 233 (1936). The New Haven Department of Health has adopted a regulation providing that no well shall be constructed within the city until information regarding it has been registered with the dept., such information to include the proposed location, the type of construction and the uses to which the water is to be put. No person, firm or corporation is permitted to use any water from a well registered under this regulation for any purpose other than that cited in the registration.—*G. C. Houser.*

Decrease of Specific Yield of Wells and Maintenance Problems. C. M. McCord. Southwest W. Wks. J., 18: 11; 11 (1937). From the experience at Memphis, Tenn. wells should produce with reasonable efficiency over a period of 25 years. Operators should keep a record of periodical measurements of gallons per foot of drawdown. Memphis water is very corrosive to the casing. Out of 25 samples of alloys, stainless steel was the most resistant. Strainers best cleaned by subjecting them to severe electrolytic action using high current density.—*O. M. Smith.*

Cooling Hot Well Water for Domestic Consumption. Anon. Eng. News-Rec., 117: 892 (1936). Artesian well water with temperature of 110°F., is being cooled to 80° by evaporation system at Riverside, California, so that it can be used for municipal supply purposes. Well, 1000 feet deep and 20 inches in diameter, tapped underground stream of hot water when drilled in 1930. Since then water has been exchanged for irrigation but this arrangement was not entirely satisfactory. System finally adopted consists of coils, over basin, through which water passes to be cooled. Film of water passing over coils, cools them by evaporation. Cooling water is delivered through headers to specially designed troughs, which distribute water evenly over coils. Well has flow of 1800 gallons per minute.—*R. E. Thompson.*

Hot Well Water Cooled for Use in City Distribution System. Anon. Eng. News-Rec., 118: 130 (1937). Further details given regarding cooling system installed at Riverside, California. Concrete basin, 25 x 175 feet in plan with walls 12 inches high, was built on ground near well. Extending length of basin and some 6 feet above it are 42 thin galvanized iron tubes 2 inches in diameter arranged in 7 vertical tiers of 6 tubes each. Cooling tubes are served at one end from 12-inch header bringing hot water from well via a booster pump. At other end, tubes discharge into 12-inch header leading to city mains. Circulating water is taken from hot well and goes first to concrete basin in which float valves maintain depth of about 4 inches. From 2 sumps in basin, pumps circulate cooling water over surface of tubes. Transfer of heat from tubes to circulating water plus evaporation cools water in tubes. There are 2 pumps, each of 1200-g.p.m. capacity, delivering to V-troughs above each tier of tubes, over which water continuously trickles. Below tiers is ½-inch mesh screen set about 5 feet above surface of pool, which causes water to fall in spray to basin below. As tubes are mounted at right angles to direction of prevailing wind, there is considerable drop in temperature during fall into basin. When in full operation, water in basin remains at about 83°F. It drops off tubes at about

88°. Temperature of well water is reduced from 110° to 85°. Efficiency varies with weather, being highest on hot, dry days. Most effective part of cooling operation is believed to be evaporation that occurs on surface of tubes but water loss by evaporation is relatively small.—*R. E. Thompson.*

Control of Private Wells Sought in New Jersey. ANON. Eng. News-Rec., 118: 81 (1937). Use of ground water for public supplies has long been under state control in New Jersey but private wells are not subject to regulation. Situation has now developed to point where essential supplies are directly menaced by uncontrolled draft by private wells. Control bills now being drafted are expected to be submitted to next legislature.—*R. E. Thompson.*

Private Water Supplies in Memphis. ANON. Eng. News-Rec., 118: 88 (1937). There are more than 150 privately owned and operated well water supplies in Memphis, total amount of water derived therefrom being more than that delivered by 2 city pumping stations. Wells are constructed according to specifications issued by city and are inspected each month. In addition, annual survey is made of all private systems. Some of systems are cross connected with city supply but check valves and other safety devices are provided to guard against contamination.—*R. E. Thompson.*

SURFACE WATER—FLOODS

Hydrologic Studies Recommended. ANON. Eng. News-Rec., 117: 487 (1936). In report submitted to National Resources Committee by subcommittee of Water Resources Committee, comprehensive program to remedy current lack of information is suggested. According to plan, federal government would establish basic network of stations to measure precipitation, snowfall, streamflow, ground water levels, evaporation, and water quality, and would share cost of adding supplementary stations to network wherever local non-federal agencies were willing to provide part of money. It is estimated that network could be established at initial cost of $3,676,500, of which federal government would provide $2,906,250 and local agencies $770,250. After first year, it is estimated, maintenance of stations would cost $1,824,000 annually, of which federal government's share would be $1,429,500.—*R. E. Thompson.*

New Cloudburst Flood Formula. I. GUTMANN. Eng. News-Rec., 117: 474 (1936). F. Pagliari, in Annali dei Lavori Pubblici of March, 1936, gives compilation of 13 phenomenal flood records on several watersheds in Italy and Sicily and fits to 7 of them curve expressed by equation: $q = \frac{2900}{90 + A}$, where q is rate of discharge in cubic meters per second per square kilometer and A is watershed area in square kilometers. Expressing q in second-feet per square mile and A in square miles, $q = \frac{102{,}500}{34.8 + A}$. Author finds that by simplifying and modifying formula to read $q = \frac{100{,}000}{37 + A}$ (equivalent to $q = \frac{2825}{96 + A}$ in metric units), better agreement with Italian as well as similar American records can be obtained. Proposed formula is primarily for watersheds of about 1 to

70 square miles in area but it can be used also for estimating phenomenal floods on watersheds as large as 350–400 square miles. The Italian records mentioned are tabulated together with records of 20 other cloudburst floods, chiefly in America.—*R. E. Thompson.*

Cloudburst Flood Formula. JOHN W. PRITCHETT AND GEORGE C. COMMONS. Eng. News-Rec., 117: 655 (1936). Data are presented showing that formula proposed by I. Gutmann (cf. previous abstract) gives flows far below those actually experienced in Texas.—*R. E. Thompson.*

Cloudburst Flood Formula. I. GUTMANN. Eng. News-Rec. 117: 905 (1936). Reply to criticism of Pritchett and Commons.—*R. E. Thompson.*

More on Flood Formulas. JOHN W. PRITCHETT AND G. G. COMMONS. Eng. News-Rec., 118: 275 (1937). Further discussion of formula proposed by I. Gutmann.—*R. E. Thompson.*

Prediction of Runoff Aided by Grouping Rainfall Data. C. H. EIFFERT. Eng. News-Rec., 117: 917 (1936). Unprecedentedly thorough and complete analysis of precipitation records made when studies of Miami Conservancy District flood control were undertaken, published as "Storm Rainfall of Eastern United States," Part V of technical reports of district, which included all available records through year 1914, was recently revised to include excessive precipitation data through 1931 and some storm studies through 1933. Chapter V of this volume deals with frequency of excessive precipitation, making use of isopluvial charts and pluvial indices. There has been more or less hesitation to use these charts and indices and purpose of present article is to make data and methods employed more helpful and to urge engineers to use and test them more extensively. Essential feature of method is to extend actual period of record by adding together years of record of number of individual stations in given area, in which uniform rainfall conditions may be assumed, to produce single record for aggregate number of years covered. Author believes method offers best available means of estimating frequency of excessive precipitation and to large extent removes limitations placed on use of data due to short periods of record. Necessity of securing additional data and records through establishment of more observation stations is emphasized, however, as no prediction or estimate can ever take place of actual record.—*R. E. Thompson.*

Better Flood Forecasting and Flood Warning Needed. ROBERT E. TURNER. Eng. News-Rec., 117: 751 (1936). Plan is suggested for reorganization and strengthening of river and flood service of Weather Bureau, giving undivided responsibility to Bureau, together with means to promote the work. Adequate, unified flood-forecasting service should be considered in any national flood-control program. Not only would such service limit to great extent justification for expensive flood-control projects undertaken because of expediency, but would make possible proper operation of flood-control projects. Adequate precipitation forecasting is very vital phase of flood fore casting.—*R. E. Thompson.*

Data Required for Flood Prediction. EDGAR E. FOSTER. Eng. News-Rec., 118: 103, (1937). Extension of precipitation stations into headwaters and divides of watersheds, establishment of more stations for obtaining hourly or continuous rainfall records, more extensive aerological soundings, and information on snow cover are necessary for flood prediction.—*R. E. Thompson.*

The Tennessee River Experiment. ANON. Eng. News-Rec., 117: 771 (1936). Comprehensive discussion of evolution of first attempt to control and develop full length of a large river and make entire resources available for benefit of surrounding region. Events leading up to creation of Tennessee Valley Authority are reviewed, huge many-sided task assigned to it is outlined, and accomplishments to date discussed. Including headwaters, river system has length of nearly 1,000 miles. Drainage basin has area of 40,600 square miles and includes parts of 7 states. Land elevations range from about 300 feet to more than 6,500 feet. Forest of some kind covers something more than half basin's 26,000,000 acres. Mean annual rainfall is about 52 inches: individual years may vary from 40 to 60 inches. In parts of eastern mountain areas, mean rainfall is as high as 80 inches. Runoff averages 24 inches. About one-quarter of 2,500,000 population is located in cities. Operations are financed in part from allocations of emergency relief-work funds and in part by Congressional appropriations. Bond issue authorized in legislation has not yet been made use of. About $100,000,000 of the $113,000,000 provided to date has been expended. II. Water Conservation and Flood Control. Ibid., 823. Conservation and flow regulation phases of project are discussed in some detail, including analysis of flow data and flood problem, storage required and its distribution, etc. Conclusion from various studies made was that ultimate storage to be provided for in comprehensive plan should be not less than 10,000,000 acre-feet and that half or more of this amount should be held in reserve for flood-control storage in headwaters. III. Navigation and Power on the Tennessee. Ibid., 860. Canalization plans and relationship of dam locations and reservoir operation to problems of navigation, flood protection and power production are discussed. IV. River and Region. Ibid., 897. Off-river problems and activities, particularly promotion of improved agricultural methods to reduce soil erosion and silting of reservoirs and control of forest and waste or submarginal land, are discussed, together with distribution and sale of electricity, development of recreational resources, etc. V. River Development on Trial. Ibid., 929. Discussion of political, economic, and organizational factors that influence the undertaking. It is too early to formulate opinion whether experiment justifies unified control and development of a great stream. Whether huge investment will ever be able to liquidate its cost on usual commercial balance-sheet is still a wide-open question. Work to date is precedent and model only in its technical activities. Problems of organizing and financing river development and establishing sound policies to guide its administration as a business and public-service undertaking remain to be worked out.—*R. E. Thompson.*

Tennessee River Valley Studied by Army Engineers. HAROLD C. FISKE. Eng. News-Rec., 117: 938 (1936). Discussion of article in December 3rd issue

(cf. previous abstract) and description of thoroughness of research into storage and river improvement prior to 1933.—*R. E. Thompson.*

Flood Control Begun. G. B. PILLSBURY. Eng. News-Rec., 118: 192 (1937). Scope and status of work authorized in flood control act of 1936, which established general policy of federal participation in flood control works, based on local participation, is discussed. Act authorizes construction of some 270 flood control projects with estimated ultimate cost of about $310,000,000, based on general surveys made for so-called 308 Reports of Corps of Engineers. In addition, survey of some 238 projects was authorized if, after preliminary examination, these are found to have such prospective merit as to warrant cost of preparing detailed plans and estimates. Federal aid in eliminating preventable flood disasters is now accepted national policy.—*R. E. Thompson.*

Droughts and Floods. JOHN C. HOYT. Eng. News-Rec., 118: 196 (1937). Countrywide conditions regarding rainfall, runoff, stream flow, water supplies and ground water levels in 1936, based upon reports of United States Geological Survey, are summarized. Abnormalty of rainfall and runoff related more to freakish distribution than to total quantities, and as result there were unprecedented floods on number of rivers and a Great Plains drought whose destructive effects equaled or approached those of 1934. Shortage of water for various uses has been largely eliminated by increased storage and other facilities provided during last 5 years. Rather general recharge of ground water reservoirs in 1935 was sufficient to create hold-over storage that was in many areas ample to supply demands in 1936 in spite of drought.—*R. E. Thompson.*

Forecasting Floodflows. WILLIS R. GREGG. Eng. News-Rec., 118: 198 (1937). Definite progress has been made in weather forecasting but science has not yet been developed to point where excessive precipitation due to unusual situations can be predicted. Conditions causing the heavy rainfalls which resulted in floods of recent years are outlined and it is pointed out that these conditions could not have been successfully forecast more than 24 hours in advance. It is also difficult to specify limited area over which abnormally heavy rains are to be expected. Benefits to be derived from such forecasting are such that they not only justify but urge further investigations in this field.—*R. E. Thompson.*

Flood Control Being Tested on the Mississippi. CHARLES S. HILL. Eng. News-Rec., 118: 222 (1937). Review of conditions and many controversies relating to adoption of Jadwin flood-control plan following major lower Mississippi flood of 1927, greatest recorded to that date, as result of which Mississippi floods were accepted as national responsibility. Plan adopted, progress made and results expected are outlined.—*R. E. Thompson.*